WATER WORKS & SEWERAGE

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L. H. Enslow
EDITOR

APRIL, 1938
VOLUME 85. No. 4

See You in NEW ORLEANS, LA.

From a small struggling French settlement founded by Bienville in 1718, New Orleans has grown to the metropolis of the South with half a million people. Its old traditions have been kept alive and its historic treasuries and distinctive customs of early life preserved.

New Orleans basks happily and securely in a mild semi-tropical sun, behind the impenetrable levees of the mighty Mississippi River, 107 miles from the Gulf of Mexico. The Heart of the old city is the Vieux Carre where will be found beauty, history and romance.

Modern New Orleans is equally fascinating with 171-foot wide Canal Street as the dividing line. An industrial city of the first magnitude, the leading wholesale and retail market of the South, its greatest financial center and port city, New Orleans sets the pace for Southern progress. Three thousand ocean-going vessels clear from here each year, while barge lines plying up and down the Mississippi and its tributaries and the Intracoastal Canal use New Orleans' eight miles of wharves as their terminus.

The City Unique, New Orleans, whose water system has been under four governments . . . the French, the Spanish, the Confederate and the American . . . extends a cordial invitation to you to attend the American Water Works Association Convention.

MARDI GRAS, New Orleans Frolic of Fun, has international fame.

PITTSBURGH EQUITABLE METER COMPANY
MERCO NORDSTROM VALVE CO.
NEW YORK · BUFFALO · PHILADELPHIA · DES MOINES · CHICAGO · COLUMBIA

SUPER-DE LAVAUD CENTRIFUGAL CAST IRON PIPE

U. S. Pit Cast Pipe

U. S. Mechanical Joint Pipe

U. S. Threaded Cast Iron Pipe

U. S. Ni-Resist Cast Iron Pipe

U. S. Cast Iron Culverts

U. S. Flexible Joint Pipe

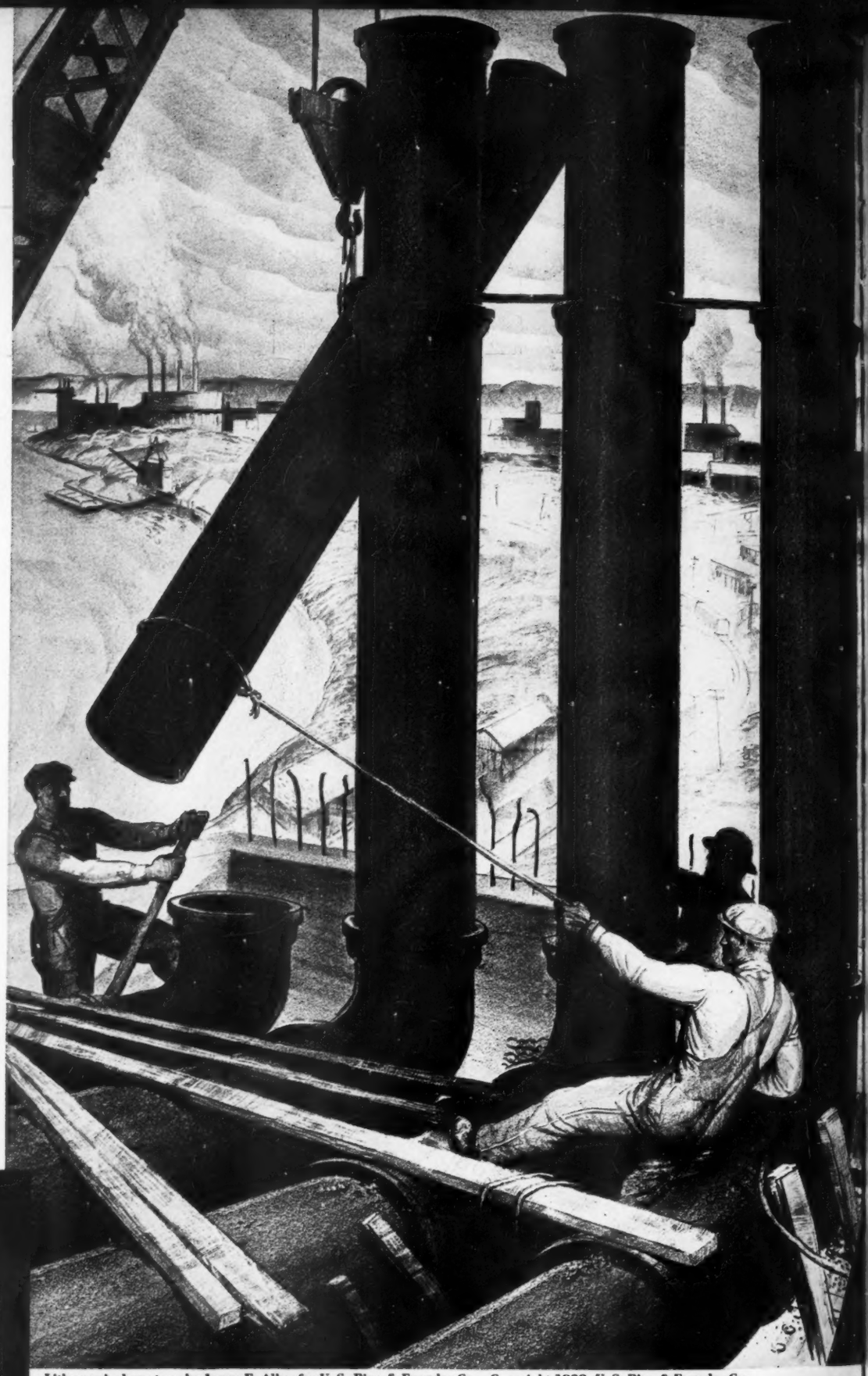
Alloy and Gray Iron Castings

U. S. Cast Iron Roof Plates

U.S. cast iron PIPE

Cast iron and alloy cast iron pipe centrifugally or pit cast — for water works, gas, sewerage and drainage service as well as industrial uses involving corrosives.

U. S. PIPE & FOUNDRY CO.
BURLINGTON, NEW JERSEY
Foundries and Sales Offices throughout the U. S.



Lithographed on stone by James E. Allen for U. S. Pipe & Foundry Co. Copyright 1938, U. S. Pipe & Foundry Co.

MANY reasons are adduced by metallurgists for the long life of cast iron pipe. None of them equals in importance the simple historical fact that the first cast iron water mains laid in Europe and America are still in service. The fundamental reason, of course, is that cast iron pipe combines in one material *all* the qualities requisite for long-lived underground service. In the case of Super-de Lavaud centrifugally-cast pipe, because it is "cast without chill in a metal mold," certain of these qualities are greatly enhanced, as for example, resistance to impact.

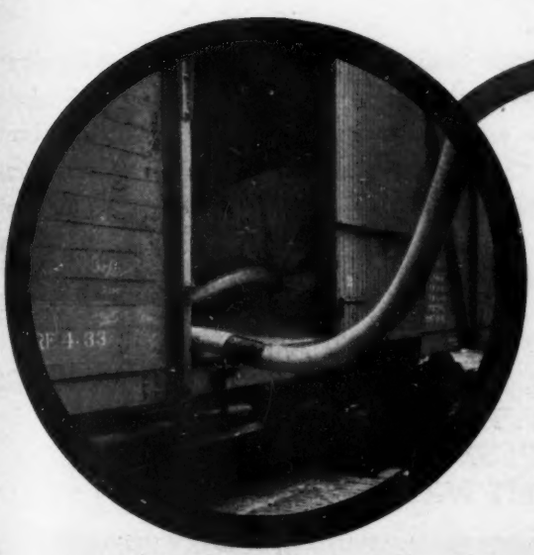
THE BEST CONVEYING SYSTEM MONEY CAN BUY

FOR
FINE, CRUSHED, AND GRANULAR
MATERIALS

The Airveyor

The organization and research facilities of the Fuller Company assure you the best engineering designs possible, and, in addition, equipment built to give lasting satisfaction . . . assets accrued through many years of experience and intimate contact with the field of conveying dry pulverized, crushed, and granular materials. Added to these facilities, a corps of service engineers of long and varied experience, is further insurance that Fuller equipment will give you the best of operating results.

These facts are conclusively borne out by the many Airveyor Systems in successful operation, and being installed. When your needs are conveying, tell us your problem. Our engineering department is always glad to submit plans and specifications.



FULLER COMPANY
CATASAUQUA, PENNSYLVANIA

Chicago: 1118 Marquette Bldg.
San Francisco: 320-321 Chancery Bldg.

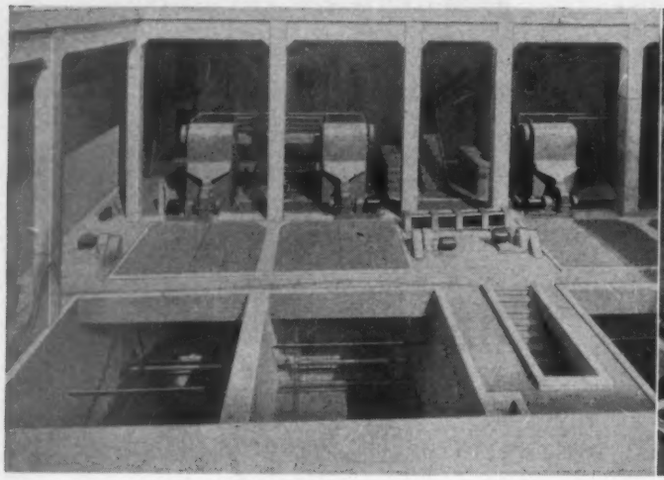
A-27

FULLER-KINYON, FLUXO, AND AIRVEYOR CONVEYING SYSTEMS · · · · ROTARY FEEDERS AND DISCHARGE GATES
ROTARY AIR COMPRESSORS AND VACUUM PUMPS · · · AUTOMATIC BATCH WEIGHERS · · · BIN SIGNALS

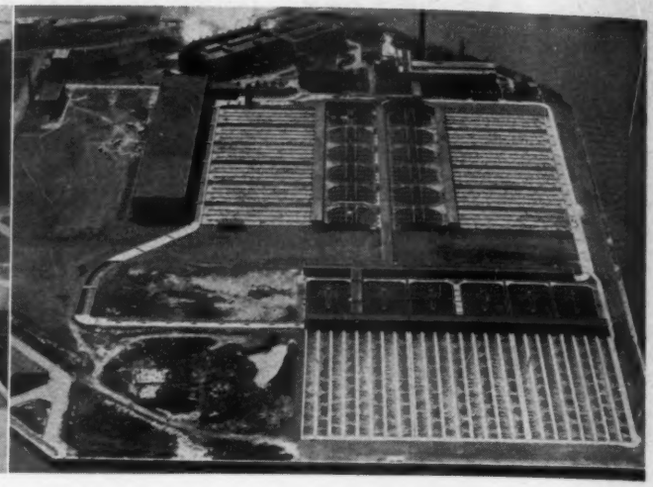
WATER WORKS AND SEWERAGE, April, 1938. Volume 85. Number 4. Published monthly at 330 South Wells Street, Chicago, Ill. by the Gillette Publishing Company. Per copy, 25c. Subscription rate, $2.00 per year; Canadian and Foreign, $3.00 per year. Copyright, 1938. Entered as Second Class Matter, June 2, 1931, at the Post Office at Chicago, Ill., under the Act of March 3, 1879.

HOW TO HANDLE IT

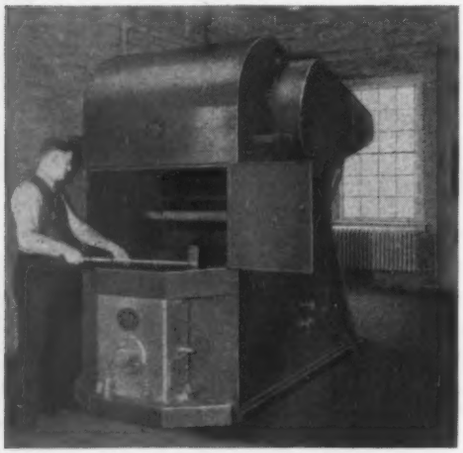
REX SANITATION EQUIPMENT



New York City (Wards Island) Sewage Treatment Plant will be served by the Bronx and also Manhattan Grit Chambers (Design Capacity 600 M.G.D.) Rex Bar Screens with grinders, also Rex Grit Collectors and Separate Washers, are installed in both of these Grit Chambers.



Milwaukee, Wis., Sewage Treatment Plant (showing new plant addition in foreground), with six Final Settling Tanks equipped with double Rex Tow-Bro Sludge Removers—Four of original Settling Tanks also Tow-Bro equipped.



Rex Triturator and Bar Screen, Highland Park, N. J. This attractive and efficient unit now provides the most advanced method of screenings disposal. Rex Triturators can be used with hand or mechanically cleaned screens and in new or existing plants.

No recommendation for Rex Sanitation Equipment could be more impressive than its choice for outstanding installations—large and small—and its continuing use by leading consulting engineers. A recognized leader in this field—Rex Sanitation Equipment installations are both numerous and widespread.

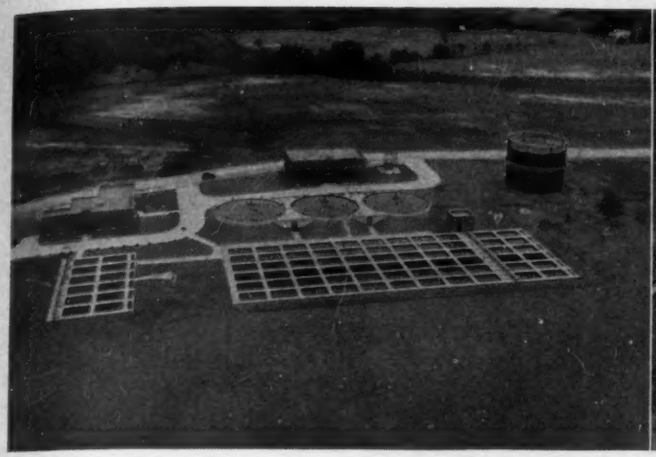
Rex Conveyor Sludge Collectors	367	units in	123 plants
Rex Tow-Bro Sludge Removers	41	units in	17 plants
Rex Grit Collectors and Washers	96	units in	19 plants
Rex Mechanically Cleaned Bar Screens	72	units in	45 plants
Rex Plunger Sludge Pumps	155	units in	76 plants
Rex Triturators	36	units in	25 plants

FINE SCREENS (Band and Drum Types)
WATER INTAKE SCREENS
MECHANICALLY CLEANED BAR SCREENS
TRITURATORS (Screenings Shredders)
TOW-BRO SLUDGE REMOVERS
CONVEYOR SLUDGE COLLECTORS
AUTOMATIC TANK SKIMMERS
PLUNGER SLUDGE PUMPS
or GRIT COLLECTORS AND GRIT WASHERS

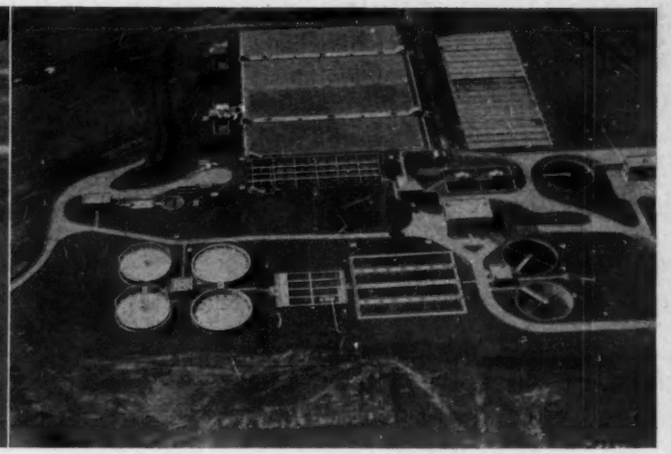
REX CHAIN BELT SANITATION

IF *IT* IS SEWAGE

PREFERRED FOR OUTSTANDING INSTALLATIONS



Durham, N. C., Sewage Treatment Plant. Rex Conveyor Sludge Collectors are installed in the six Primary Settling Tanks (left center) and the six Final Settling Tanks (right center) of this new, efficient Activated Sludge Plant.

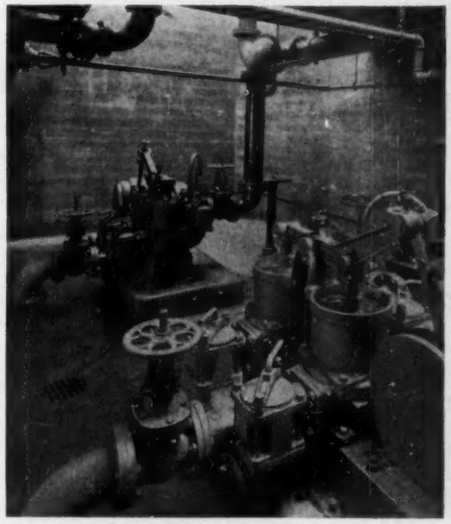


Madison, Wis., Sewage Treatment Plant with new Activated Sludge Plant in foreground. Rex Bar Screens, Rex Grit Collectors and Washers, Rex Conveyor Sludge Collectors, Rex Plunger Sludge Pumps, and Tex Tow-Bro Sludge Removers serve this outstanding plant.

TO THE MUNICIPALITY Rex Sanitation Equipment offers moderate price, attractive appearance, and long life.

TO THE PLANT OPERATOR it offers efficient performance, trouble-free operation, and easy maintenance.

TO THE CONSULTING ENGINEER it offers client-satisfying performance and appearance, also a reflection of credit for its choice (because of superiority) apparent even to the layman.



Rex Plunger Sludge Pumps, Washington, D. C. These two units are typical of twelve Rex Pumps handling primary sludge at this plant. The eight Rex Grit Collectors and Washers also installed here are noteworthy—being completely covered by concrete slabs and earth fill above.

Consult our nearest Branch Office or write our Engineering Department, Sanitation Equipment Division, Milwaukee, Wisconsin, for catalogs, suggested specifications, and a typical drawing of equipment suitable for your requirements.

COMPANY *of Milwaukee*

EQUIPMENT

PROGRESS in Sewage Treatment Equipment for 45 years!

P. F. T.

P. F. T. Equipment is accepted as standard today because men of vision started over 45 years ago to specialize in the development and building of sewage treatment equipment. That they have kept steadfastly on their course is evidenced by the constant flow of improvements P. F. T. has engineered, and by thousands of installations.

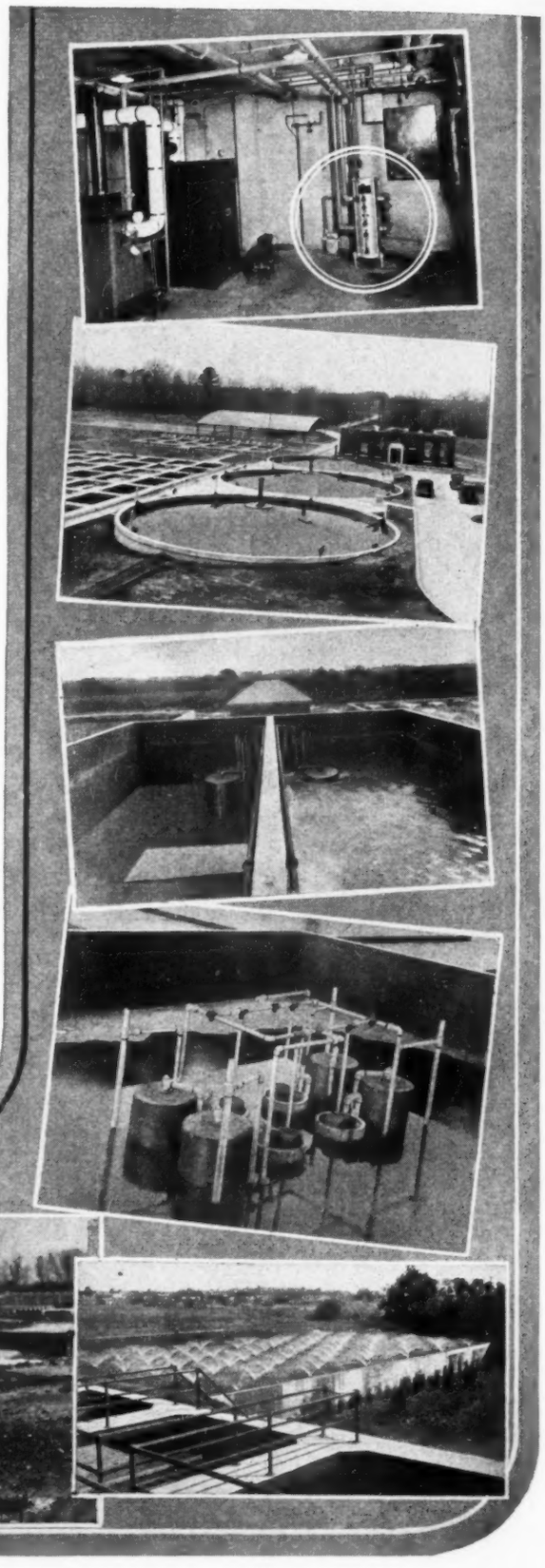
From the beginning, P. F. T. has extended its friendly cooperation to consulting engineers and municipal officials. P. F. T. engineers' experience, knowledge and ability to serve embraces installations of every size — from the largest cities to the smallest towns.

Among P. F. T. Equipments in wide favor today are P. F. T. Rotary Distributors, Floating Cover Digesters, Sprinkling Filter Plants, Flame Traps, Waste Gas Burners, Twin Tank Controls, Alternating Siphons, Dosing Tank Counters, Sludge Pumps and other accessory devices.

May we send you bulletins on any or all of the complete line of Specialized P. F. T. Sewage Treatment Equipments?

PACIFIC FLUSH-TANK COMPANY
4241 Ravenswood Avenue
Chicago, Illinois

New York Los Angeles Charlotte, N. C.

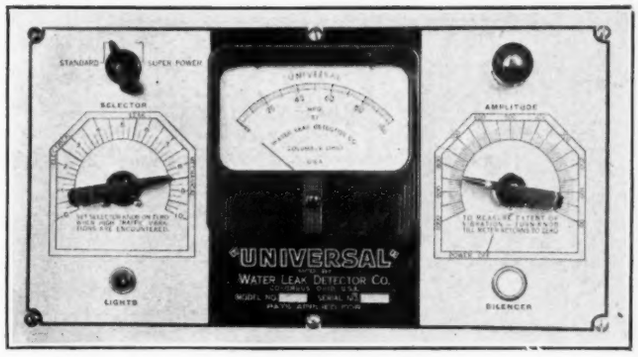


"UNIVERSAL METHOD"

OF

WATER LEAK SURVEY

WITH YOUR OWN MEN



SUPER-POWER PANEL

You can eliminate guess work entirely with the "UNIVERSAL" Measured Sound Method. Visual amplitude recording eliminates mistakes caused by the failings of the human ear. And having located the leak, by a simple process its approximate size can be determined in advance of excavation.

You owe it to your city to modernize your water department with "UNIVERSAL" Water Leak Survey instruments. Make your own survey at the minimum of cost to fit your own particular need.

The "UNIVERSAL" Super-Power (Converter type) instrument (shown below) is built to enable the water leak survey engineer to detect VERY SMALL LEAKS at long distances through hydrants and valves, and also to locate these small leaks under the pavement.

We will furnish an experienced instructor upon request to train your men. The time and cost involved may well be repaid within the first week.

This same instrument, with extra attachments, will locate your buried pipe lines.

Demonstrations given upon request and without any obligation.

The new 1938 Model Super-Power (Converter Type) "Universal" Water Leak Survey Equipment

WATER LEAK DETECTOR CO.

155 N. THIRD ST. **COLUMBUS, OHIO**

BRANCH OFFICES:

142 Ashland Place, Brooklyn, N. Y. | 1403 Oliver Building, Pittsburgh, Pa. | 419 Smith Tower, Seattle, Wash.

58 Pelham Ave., Toronto, Ontario, Canada

A NEW DAY *in*

As mile after mile of Transite Pipe goes down all over the country, men concerned with economical water transportation will do well to review the reasons behind the success of this remarkable material

THIS is a story that goes back to the days of ancient Rome. And to one of the world's greatest engineering feats . . . the Roman aqueducts.

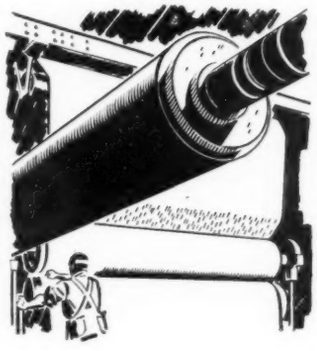
Wherever an arch still stands . . . there also stands eloquent testimony to the wisdom with which the Romans built their water-carrying systems. Two thousand years of proof for the durability of stone.

Now . . . with the established success of a modern *non-metallic* carrier, Transite Pressure Pipe . . . comes another new day in water transportation.

Transite Pipe is a mixture of asbestos and cement, formed under high pressure into a dense, homogeneous structure. The asbestos fibers, evenly distributed, not only do for Transite Pipe what steel does in reinforced concrete, but also provide uniform strength values throughout the material.

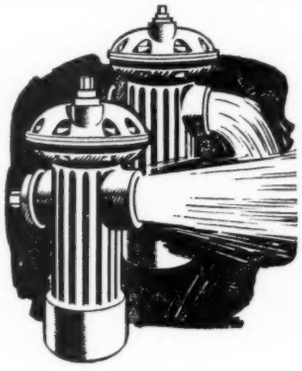
Tuberculation A Physical Impossibility

It is now generally recognized that a pipe line, though structurally intact at the end of twenty years, may actually prove a most decidedly uneconomical installation if tuberculation has reduced its carrying capacity and caused a corresponding increase in pumping costs.



Fortunately, this cannot happen to Transite Pipe. To begin with, the huge mandrels used in forming this modern water pipe give its interior wall a smoothness that offers minimum frictional resistance to water flow.

What happens after installation is even more pertinent to economical water transportation. Transite's high initial flow coefficient—C-140—remains high, year after year! Being non-metallic, Transite Pipe cannot tuberculate. In this simple fact lies the secret of low pumping costs that stay low.



Johns-Manville TRANSITE

Water Works and Sewerage—April, 1938

Water Transportation...

Corrosion Resistance and Immunity to Electrolysis

The enormous toll exacted each year in this country by the destructive ravages of soil corrosion is too well known to require further comment here.

But . . . because this is true, it is well to remember that Transite Pipe is made of asbestos and portland cement. And that these two imperishable materials have already established a time-proved record for exceptional resistance to the chemical action of soil acids and salts.

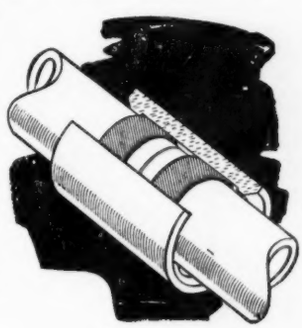
Moreover, this same non-metallic composition provides immunity to electrolysis. And this is an especially important consideration whenever pipe is installed near power lines or electric railways.

Durability . . . freedom from tuberculation . . . resistance to corrosion . . . immunity to electrolysis . . . what is the sum total of these advantages? For one thing, maximum assurance against shutdowns and cleaning expenses. For another, virtually no maintenance or replacements. In short, then, years of *truly* economical water transportation!

When Do the Savings Start?

Those years of economical water transportation start right at the day of installation! This modern water pipe, for all its great strength, is relatively light . . . handles easily. It is being installed every day in the year by unskilled crews, without using mechanical equipment on all but the largest sizes.

And the Simplex Couplings, which assure permanently bottle-tight joints on the line, also provide for rapid, foolproof assembly. Because no caulking is necessary, the trenches can be held to minimum width. Hence, in every respect, Transite Pipe installations are decidedly economical.



THIS NEW BROCHURE

gives complete information on the advantages of J-M Transite Pressure Pipe. For your copy, write Johns-Manville, 22 East 40th Street, New York City.

Be sure to see the
J-M TRANSITE PIPE EXHIBIT
at the
A.W.W.A. CONVENTION
NEW ORLEANS APRIL 25-29

PRESSURE PIPE

An Asbestos Product
Listed by the Underwriters' Laboratories, Inc.

WHAT IS THE LIFE EXPECTANCY OF A TEST TUBE?

Just as insurance actuaries can tell you the life expectancy of any average group of men, so the heads of large laboratories and the purchasing departments of many schools, hospitals and industries have a table of mortality for their technical glassware. They can estimate the life of a gross of test tubes almost to the month.

There is no guesswork in their purchasing. Experience and comparison have proven there is a difference in test tubes. That one lot will last just so long, and another lot so many weeks longer. Therefore, they figure tube costs not by the dozen, but by the year.

Such departments have proven that Pyrex brand test tubes have a longer life expectancy and, consequently, a lower replacement cost.

There are three definite reasons for this superiority—resistance to thermal shock—resistance to mechanical shock and resistance to chemical attack and clouding. Pyrex test tubes have the lowest co-efficient of expansion of any test tubes of commercially made glass—.0000032. They are practically exempt to breakage from heat. Test tubes of "Pyrex" brand glass are heavier, have stronger walls that resist the wear and tear of classroom and laboratory use.

These are the reasons Pyrex brand test tubes have a longer life expectancy. These are the reasons laboratories prefer them and purchasing departments specify them. For *all* test tubes—for *all* uses—it pays to standardize on Pyrex Laboratory Glassware.

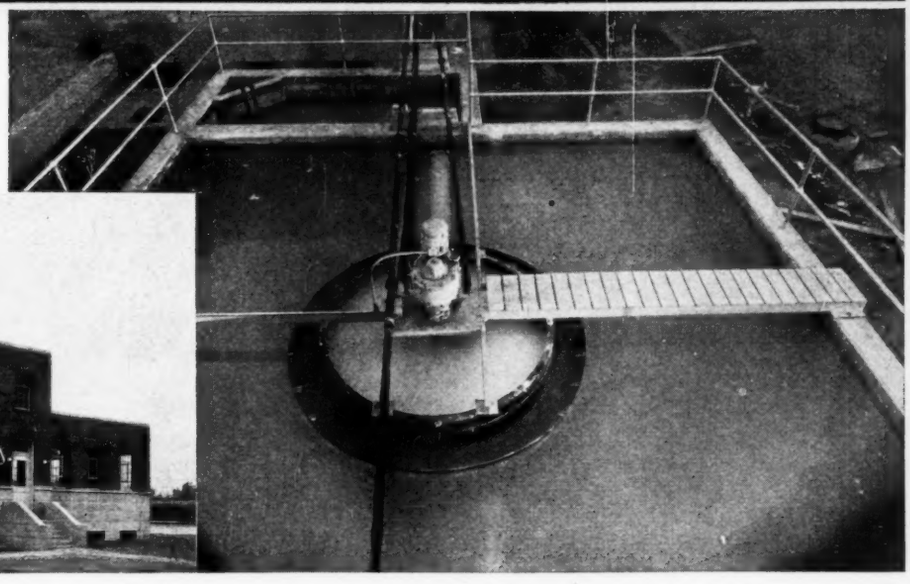
CORNING
means
Research in Glass

T.M. REG. PYREX U.S. PAT. OFF.

"PYREX" is a registered trade-mark and indicates manufacture by

CORNING GLASS WORKS • CORNING, N. Y.

Accelator
Water Softener
City of Anna, Illinois
Warren & Van Praag, Inc.
Decatur, Illinois
Consulting Engineers



The ACCELATOR
WATER SOFTENER

The Accelator represents a revolutionary advance in the art of water softening. It departs from all prior practice, obtains results heretofore unobtainable and does this within a time and space previously believed impossible.

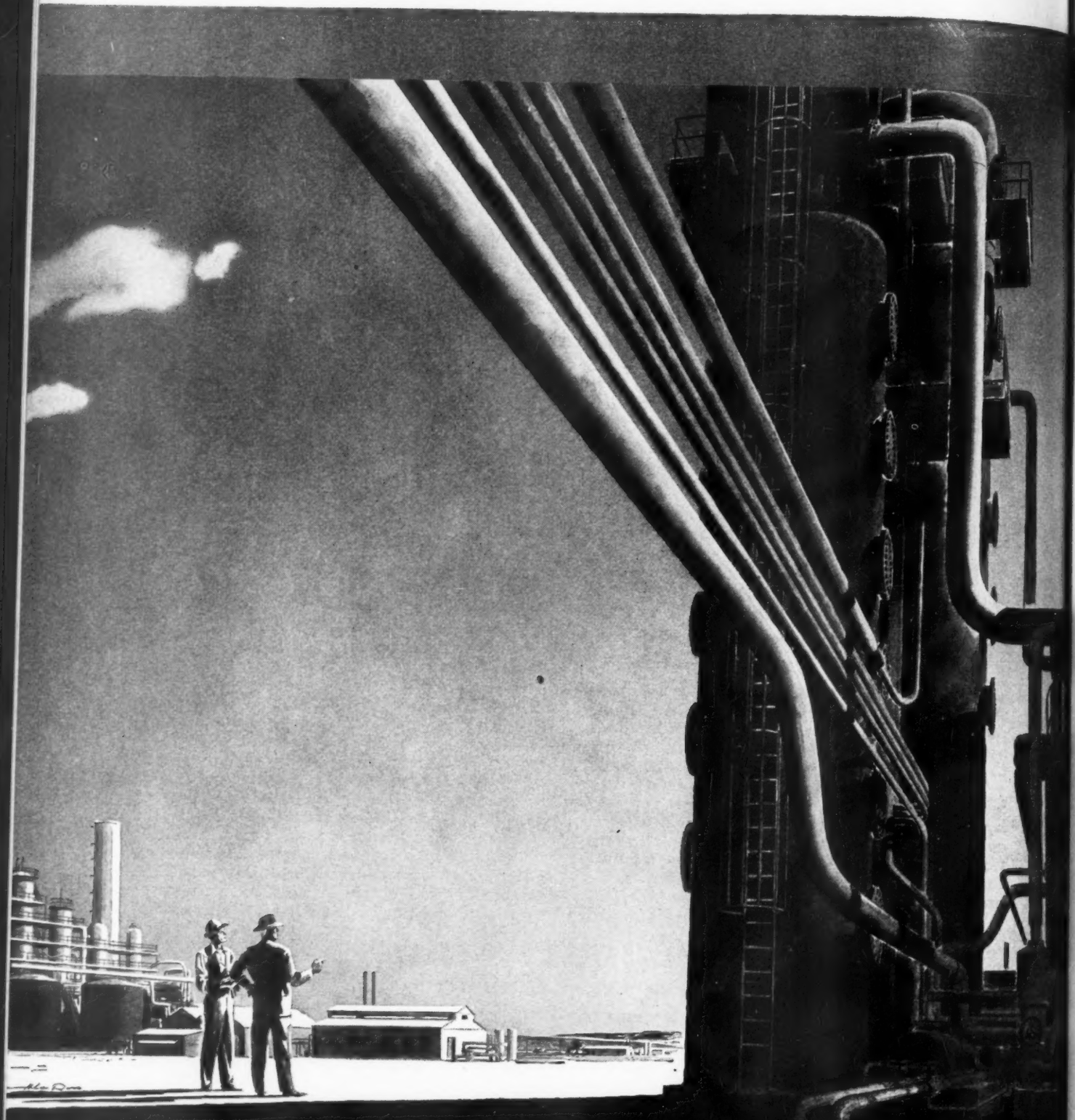
The Accelator Water Softener is another result of almost twenty-five years' research by Infilco's technical staff. Although the first actual sale was not made until 1935, the phenomenal success led to such ready acceptance that there are now twenty Accelators in service and eight under construction.

The Accelator Water Softener retains all the advantages of the well-known lime or lime-soda process and adds many new advantages of its own. It delivers a water of surprisingly low mineral content, low alkalinity, low hardness and low turbidity from an apparatus of unbelievably small size.

In the Accelator the treating reagents are applied to the water in a new way and the reactions take place under a new set of conditions. Mixing, reaction and clarification are all carried out in such incredibly small space that the area of the Accelator is usually no larger than that of the filters.

INTERNATIONAL FILTER CO.
59 E. Van Buren St., Chicago, Ill.

Koppers Engineers turn another "nuisance" into



" into a money-making product . .

SEE IF KOPPERS MAKES IT

WHEN OIL REFINERIES "CRACK" OILS to make gasoline, fixed gases are given off. Most of these refinery still gases (as well as some natural gases) contain large quantities of hydrogen sulfide.

Now hydrogen sulfide is a valuable commodity . . . but *not* when it is in gases which are to be utilized commercially.

If the gas is to be further processed, hydrogen sulfide may have an injurious effect upon the process and equipment. If the gas is to be used for heating, the hydrogen sulfide may cause objectionable odors.

One valuable thing which can be obtained from hydrogen sulfide is sulfuric acid. The oil refineries which produce the refinery still gas use large quantities of sulfuric acid in their oil refining processes.

They were in the peculiar position of having to buy sulfuric acid from others . . . and at the same time they burned hydrogen sulfide from which sulfuric acid could be obtained.

This problem was brought to the Koppers engineers because they have had the broadest experience in the purification of gases.

To solve it, the Koppers engineers developed a completely new method of purification, called the Phenolate Process.

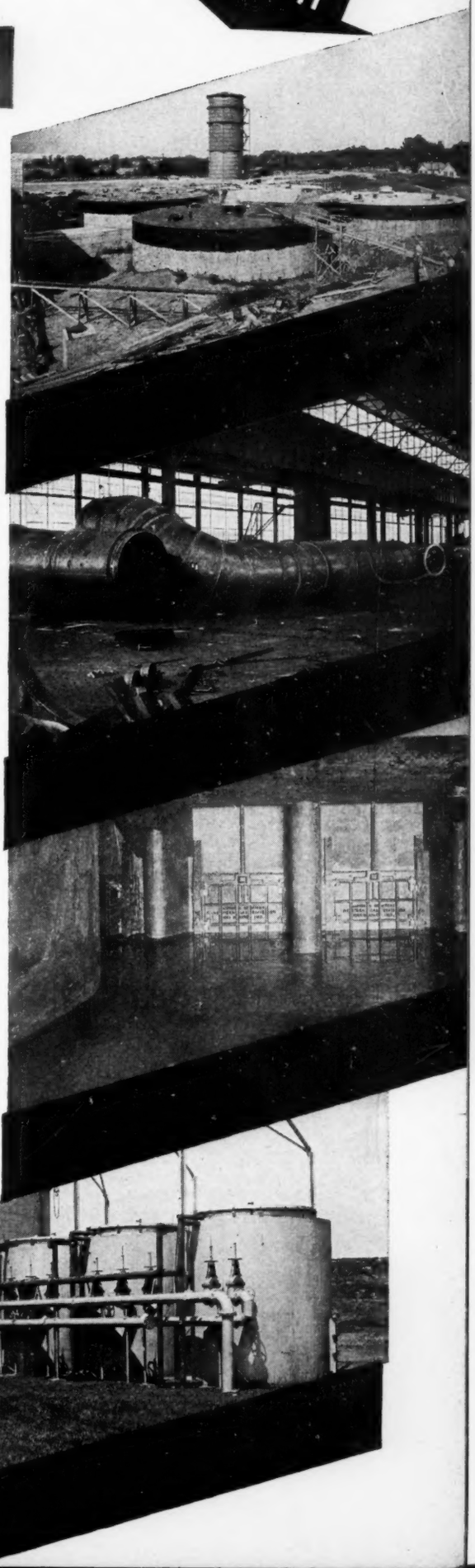
It requires only a small, compact plant. It removes from 95% to 99.8% of the hydrogen sulfide. It recovers it in a form which is most readily converted into sulfuric acid. It is inexpensive to build. It is easily maintained. It pays for itself very quickly.

• • •

Perhaps you will never be in a position where you would want to buy a phenolate plant . . . but there is a valuable lesson for you in the story of the Phenolate Process.

Again and again, Koppers engineers have done some trail-blazing job like this. Perhaps they may be able to do some trail-blazing on a problem that confronts your company. May we have an opportunity of discussing it?

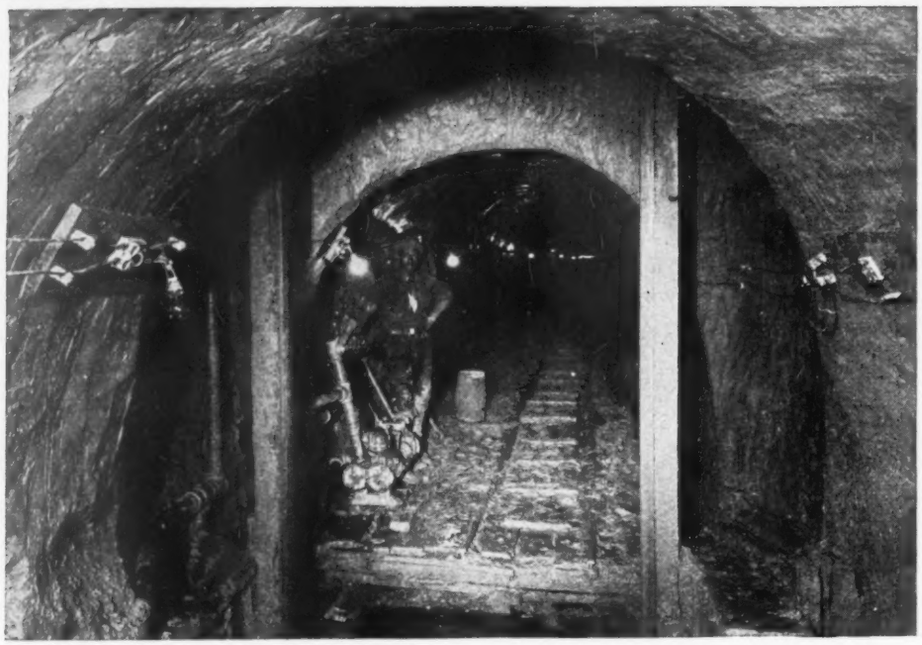
KOPPERS COMPANY . . . PITTSBURGH



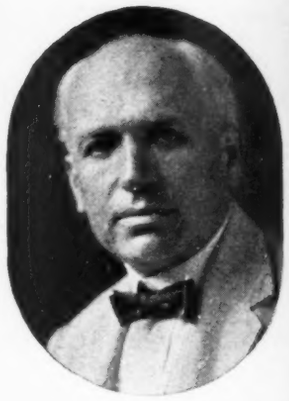
KOPPERS DIVISIONS, SUBSIDIARIES AND AFFILIATES

Hammered Piston Ring Division · Bartlett Hayward Division · Tow Boat Company · Eastern Gas and Fuel Associates · Engineering Construction Division · Gas and Coke Division · The Koppers Coal · Koppers-Rheolaveur Company · The Maryland Drydock · Mystic Iron Works · Mystic Steamship Company · National & Creosoting Company · New England Coal & Coke Company · and Chemical Division · Western Gas Division · The White Tar · of New Jersey, Inc. · The Wood Preserving Corporation ·

HOW CHARLESTON'S NEW 18½-MILE TUNNEL WAS STERILIZED



CHARLESTON'S NEW TUNNEL TO THE EDISTO RIVER WAS BUILT THROUGH MARL FORMATION. NO LINING WAS USED.



JAMES E. GIBSON, Manager and Engineer of the Charleston, S. C., Water Department who had charge of the entire tunnel undertaking—the man who made Charleston's dream come true.

A JOB THAT CALLED FOR HTH

CHARLESTON citizens gasped when three far-sighted engineers proposed a tunnel to the Edisto River for the city's water supply. But that was back in 1853. A few months ago the last 18½ miles of that "impossible" 23-mile tunnel were sterilized and put in service; a 75-year old dream had become a reality.

How Charleston's own Water Department, under the generalship of James E. Gibson, built 23 miles of unlined tunnel through marl formation is a story of unusual engineering accomplishment. No innovation, however, was the well-tested method of sterilization selected for the completed tunnel.

"We gave the matter careful thought," writes Mr. Gibson, "and finally reached the conclusion that the use of High Test Hypochlorite was the most feasible and practical method of securing the desired results. We accordingly purchased from The Mathieson Alkali Works (Inc.) 500 pounds of High Test Hypochlorite."

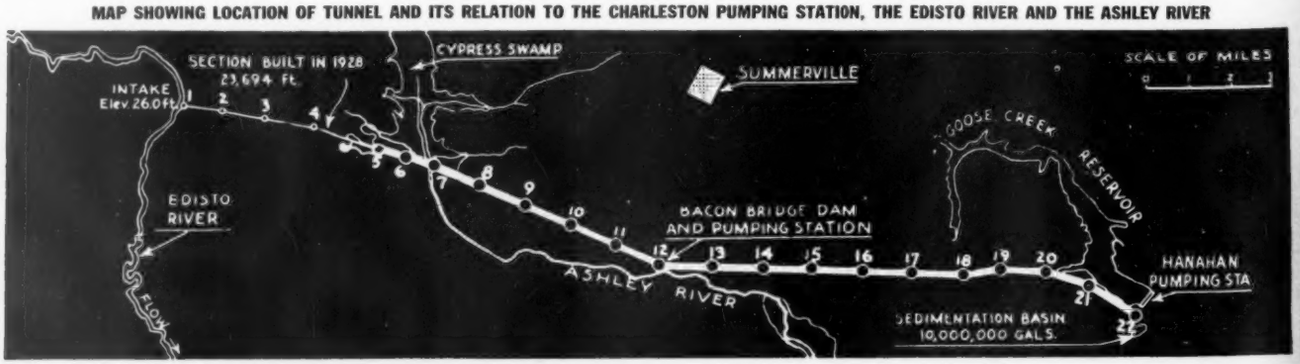
Mr. Gibson then goes on to describe how the tunnel was sterilized, how the easily-transported hypochlorite was introduced in the tunnel at different points, how the water was first admitted from the Edisto River and then from Goose Creek and finally washed out into the Ashley River through the outfall gates at Shaft No. 12. Commenting upon the effectiveness of the sterilization, Mr. Gibson states that "bacteriological tests of the discharge from the shaft through the tunnel compared favorably with tests of the raw water in the river at the intake."

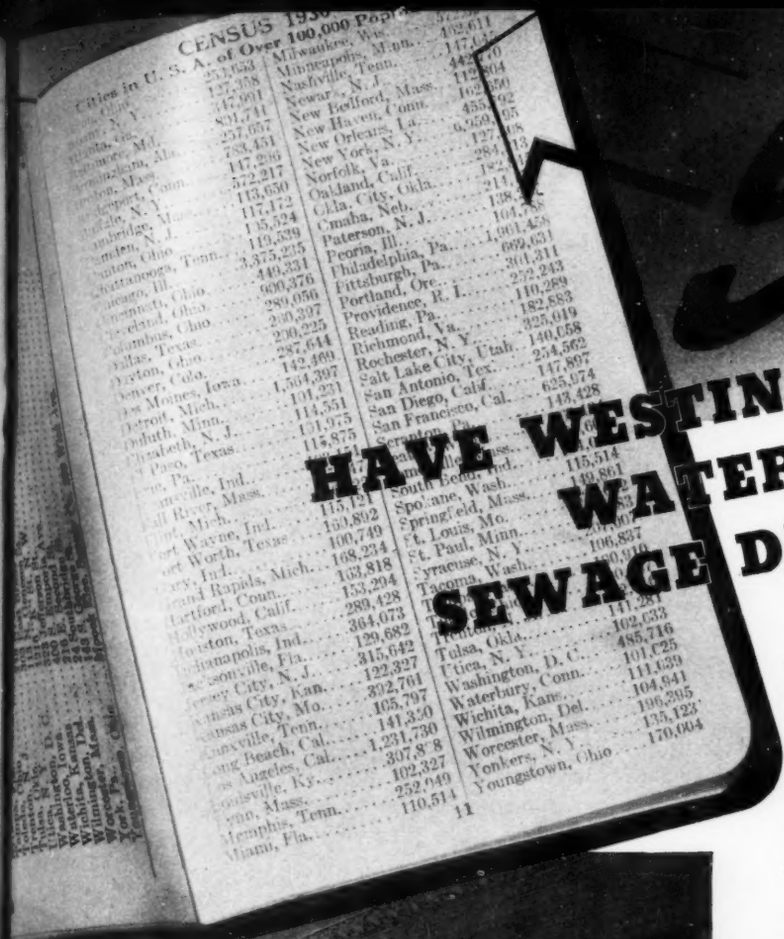
Water works men aren't often faced with the task of sterilizing such a stretch of tunnel. But Mr. Gibson's experience is typical of that of hundreds of others who have found HTH indispensable for all manner of special and emergency chlorination jobs, from treatment of an isolated well to chlorination of an entire reservoir.

Scores of just such unusual jobs, as well as many routine jobs, are discussed in detail in "Hypo-Chlorination of Water," an 80-page manual of practical information for water works officials. Send now for a copy of the new third edition.

The* MATHIESON ALKALI WORKS *(Inc.)
60 East 42nd Street New York, N. Y.
Soda Ash . . . Liquid Chlorine . . . Bicarbonate of Soda . . . HTH and HTH-15. . . Caustic Soda . . . Bleaching Powder . . . Ammonia, Anhydrous and Aqua . . . PH-Plus (Fused Alkali) . . . Dry Ice (Carbon Dioxide Ice)

MAP SHOWING LOCATION OF TUNNEL AND ITS RELATION TO THE CHARLESTON PUMPING STATION, THE EDISTO RIVER AND THE ASHLEY RIVER





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FORTY-EIGHT of the ninety-four U.S. cities with a population of more than 100,000 are served by at least one water works or sewage disposal plant largely electrified by Westinghouse. These cities are assured of dependable, economical operation with Westinghouse equipment because:

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3. ***Unexcelled Testing Facilities*** subjects Westinghouse equipment to punishment far beyond the requirements of actual service.
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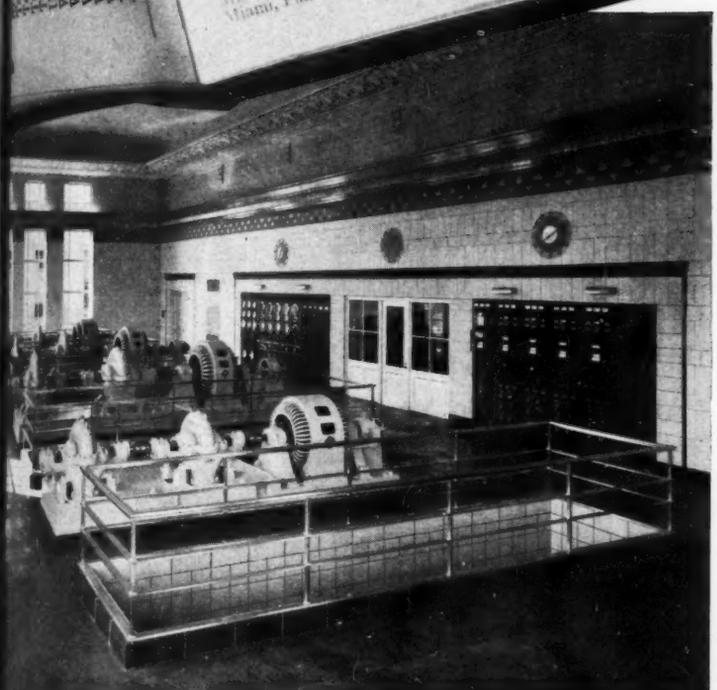
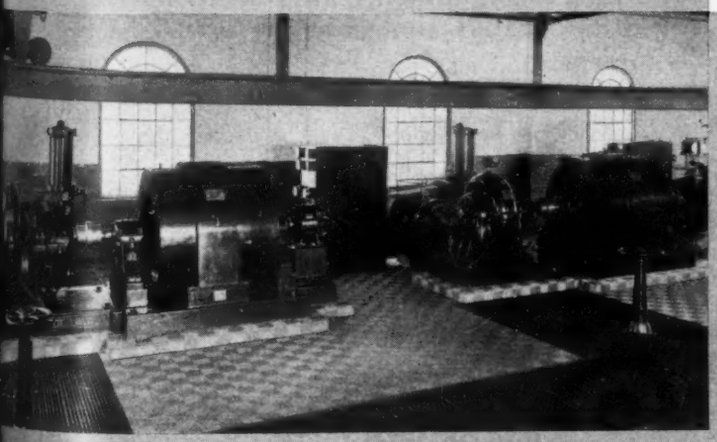
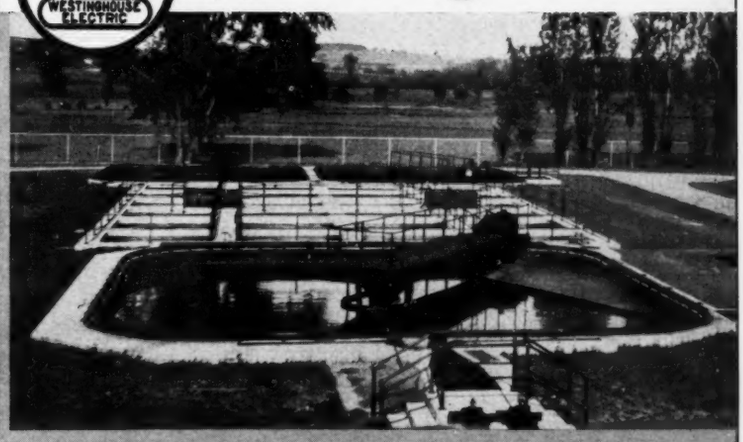


inghouse Synchronous Motors and Switchboard are typical of the careful planning the Western Hills Station, Cincinnati, Ohio.

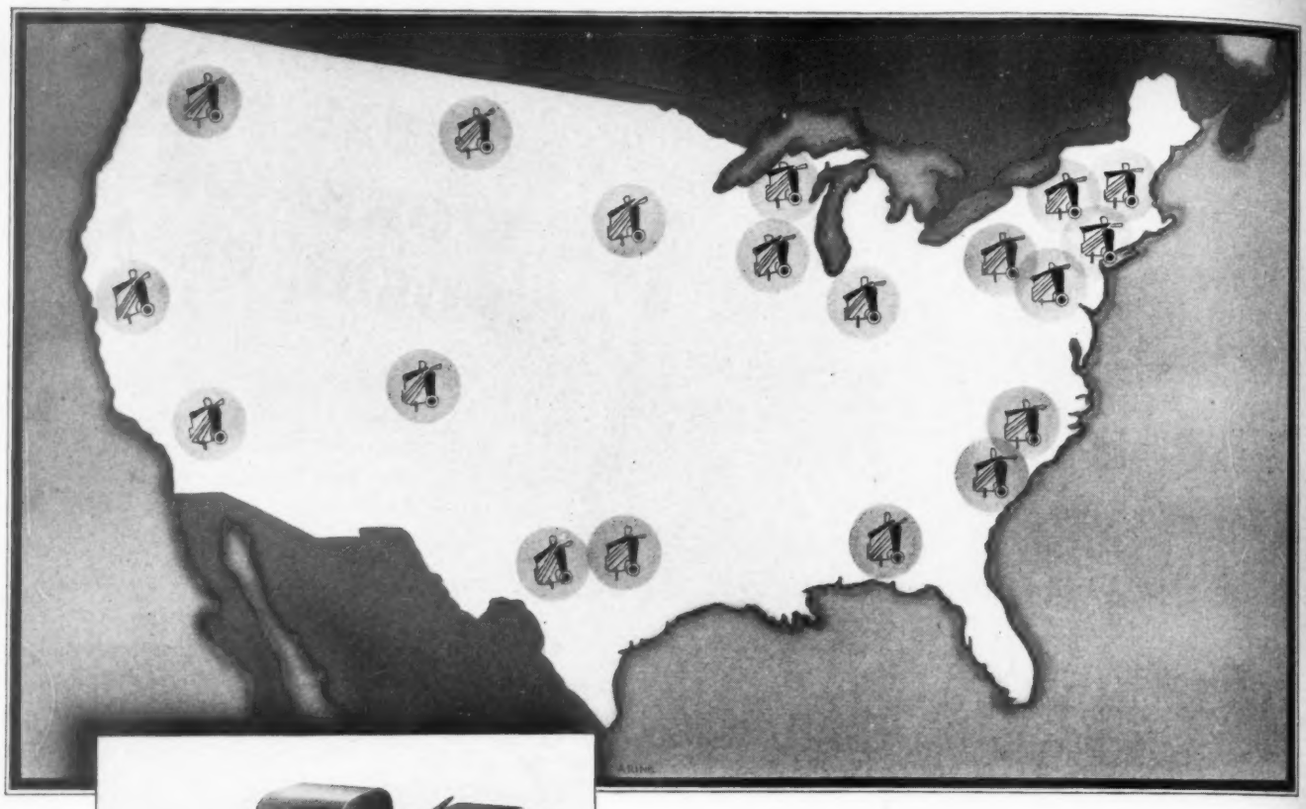




the electrical equipment for the East Park Booster Station, Philadelphia, Pa., was

Even in villages such as Newark, N.Y., the dependability of Westinghouse equipment

From Coast to Coast—It's ROYER!



Model C-2 illustrated above—Machines made in four sizes—either belt, gasoline engine, or electric drive. Pneumatic tires standard on all models.

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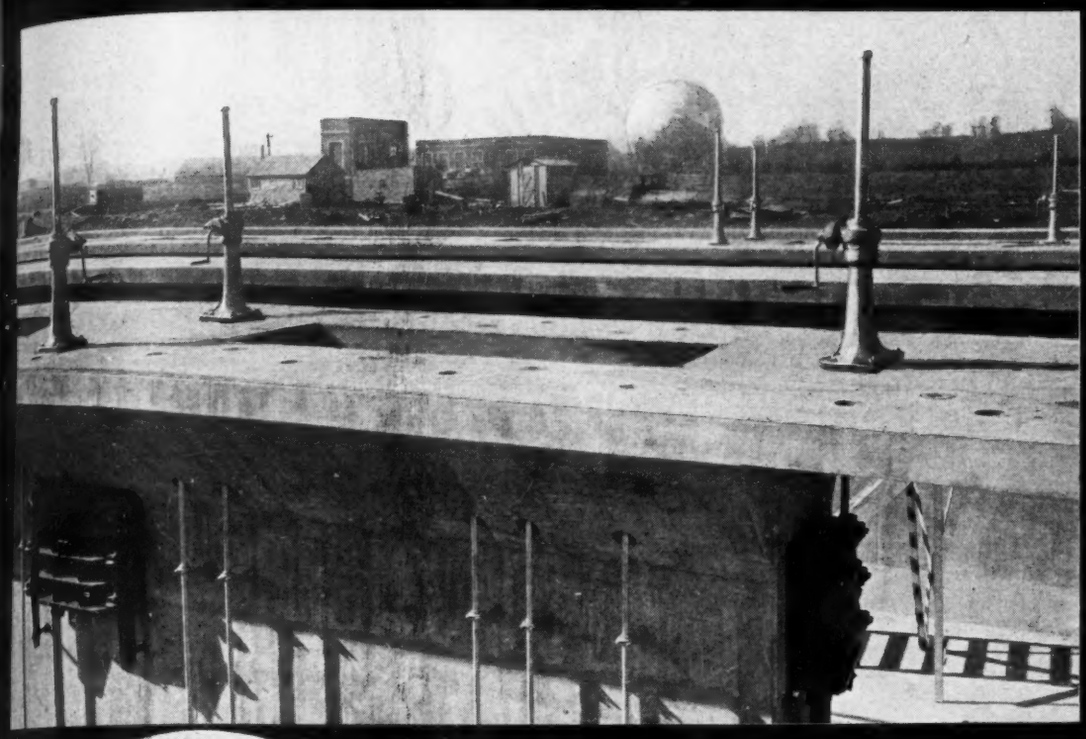
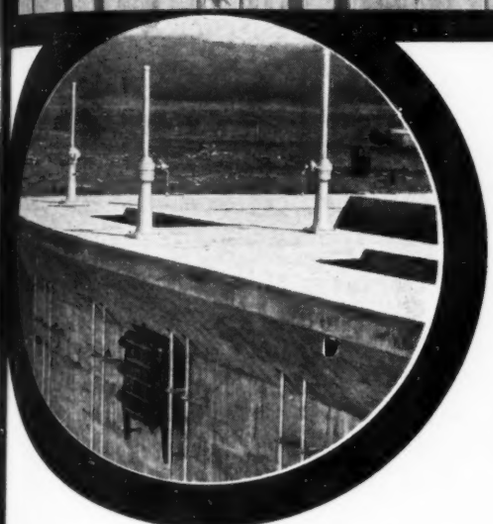
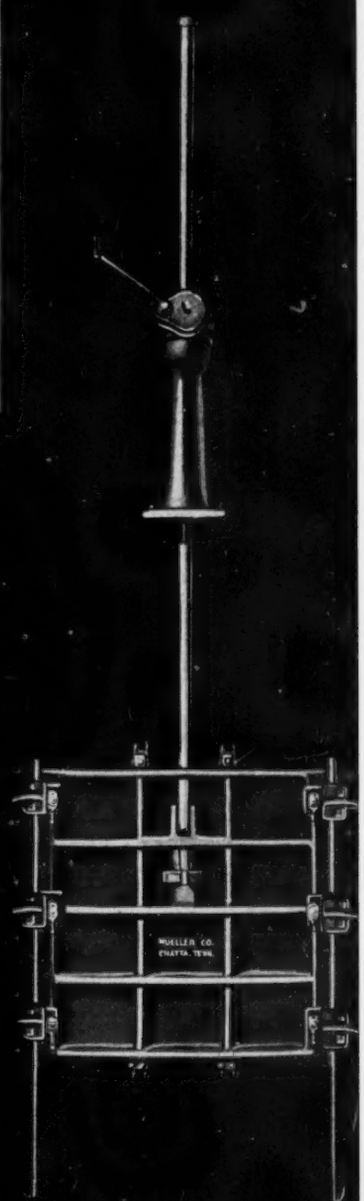




In their new Sewage Disposal Plant, Cleveland Ohio installed regular Mueller–Columbian Rising Stem Square Sluice Gates that open downward and are operated with geared floor stands. Since the gates were for unseating pressure, top, bottom and side wedges were included to insure tight closing. Engineers: George B. Gascoigne Company. Contractors: Lundoff-Bicknell Company.



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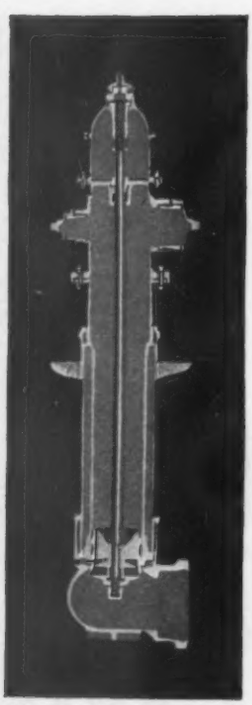

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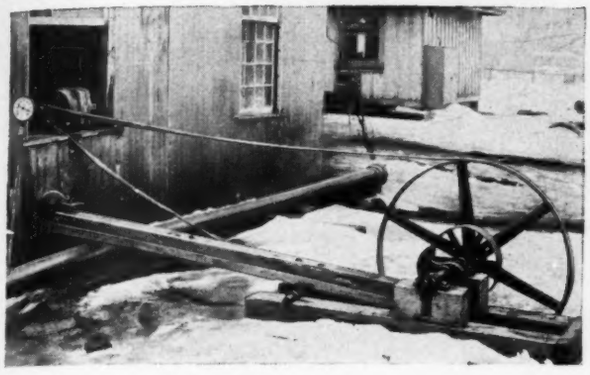

To See what could be done to *kill* a joint made with Tegul-MINERALEAD, we set up two sections of 4-inch Bell & Spigot pipe, forming a span 19′ between supports.

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Fifteen Hours of steady pounding—90,000 punishing impacts—90 lbs. water pressure maintained in the pipe—and, at the end of the ordeal, *there wasn't even a sign of a leak.*

No jointing you do in actual service will ever have to stand such cruel punishment as this—but the jointing compound that can "take it" like this, won't fail in service, no matter how severe the test. Joints made with Tegul-MINERALEAD are *Permanently Tight.*

and it came up SMILING

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The ingot form in which Tegul-MINERALEAD comes, is impervious to rain, snow and flood. These ingots can be stored outdoors on the job in any weather.

Further advantages of the ingot form include: easy handling—ingots weigh 10 lbs.; no possibility of composition changing in transit; melting pot may be replenished without interrupting the job.

Skilled labor is not required to work Tegul-MINERALEAD.

In addition to the above advantages, Tegul-MINERALEAD speeds up the job, because:

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Users report that Tegul-MINERALEAD cuts the high cost of labor, and material spoilage due to dampness and changes in composition in shipment—and definitely hastens completion of the work and clearing up of the premises.

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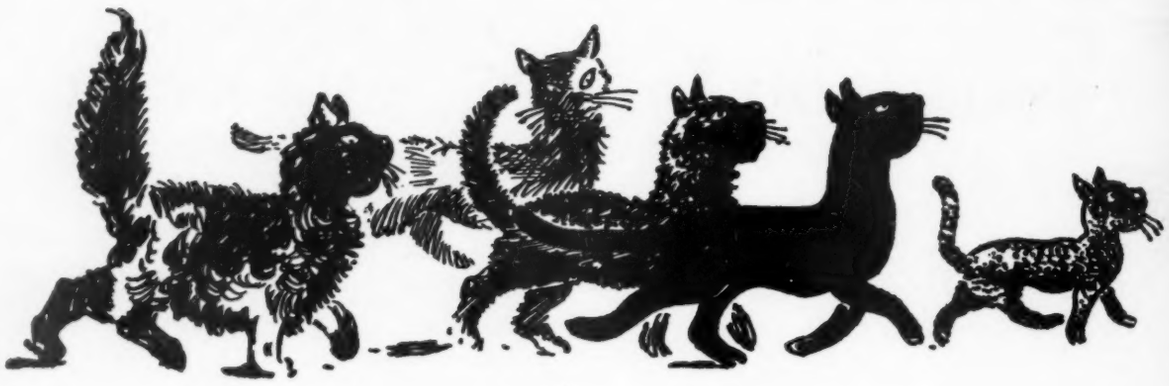
A MODERN FABLE



Some years ago there appeared at various water treatment plants in a certain country large black cats which were given an enthusiastic welcome because of their peculiar and hearty appetites for tastes and odors in water, instead of the more conventional diet of rats.

The creatures were rather elusive, however, and despite their almost continuous presence at many plants, no one was ever able to gain very complete knowledge about their habits.

Water works men agreed pretty well that some of the cats had better appetites, and behaved themselves better in the plant than others. But they couldn't seem to agree where the cast worked best. Some reported that the raw water was best. Others preferred the settling basins, and still others allowed the cats right on the filters. Similarly, it was hard to decide what breed of cats did the best job regardless of the feeding point. A number of men happening to brush against their cats in the dark found them large and bushy, and announced that cats had to be large and bushy to do a good job. Other men, noticing a carbolic odor about their cats, announced that cats with a fondness for phenol were the only kind to have.

At any rate there was a lively interest in the subject, and many entirely sincere attempts were made to investigate it. Gradually the conviction grew that above all the cats had to have large appetites and good digestive systems to retain their food regardless of their size, color, shade, or other characteristics. It became necessary to find a way of measuring their appetites in terms of what they actually ate, and when the threshold odor test provided this, all that was needed to clarify the whole subject was the application of certain well-known laws about cat behavior to the data so obtained.

Of course, this is really not a story about cats but about activated carbon.

MORAL: ***The only way to judge an activated carbon is by its capacity to remove taste and odor from water.***

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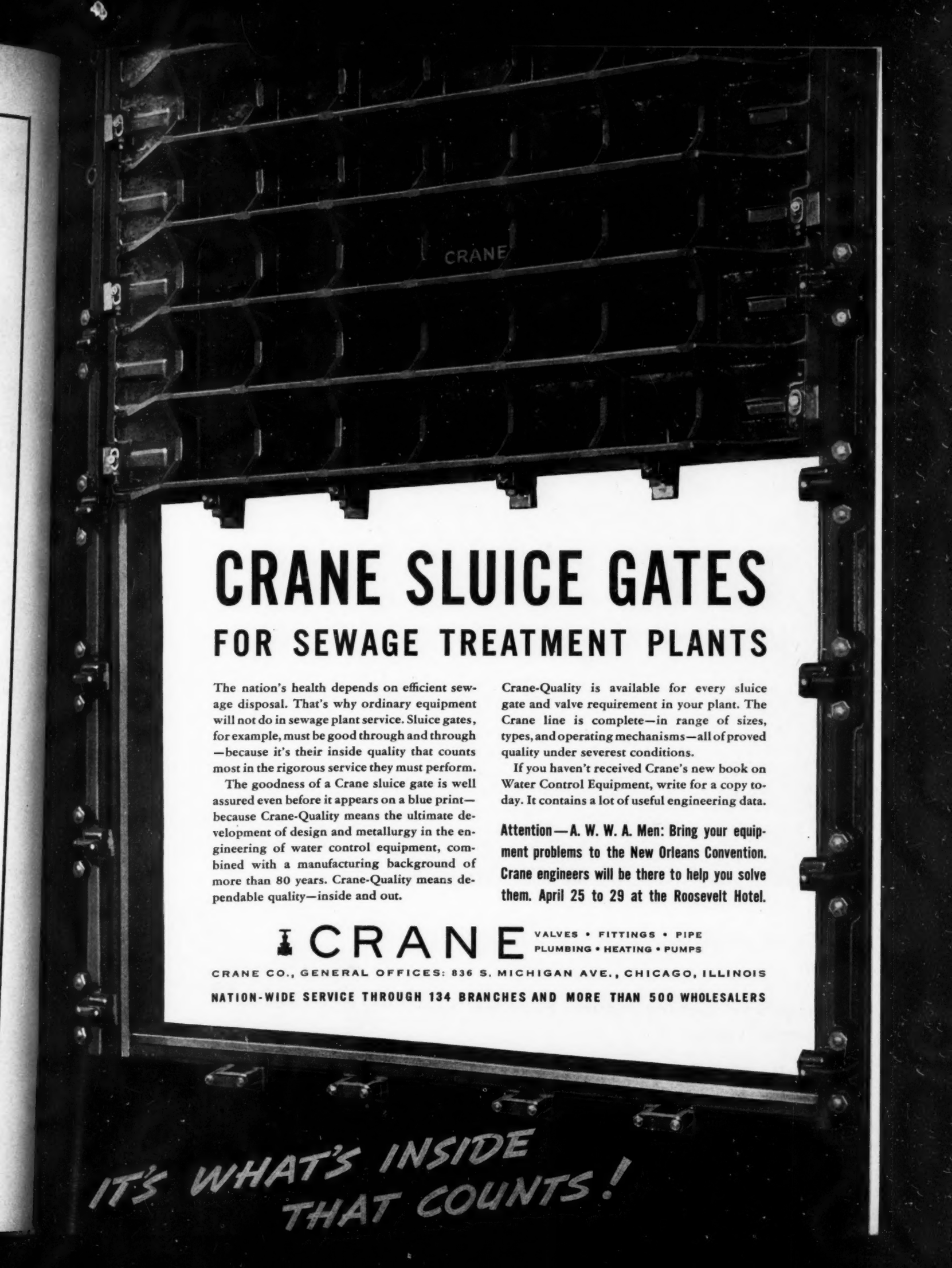

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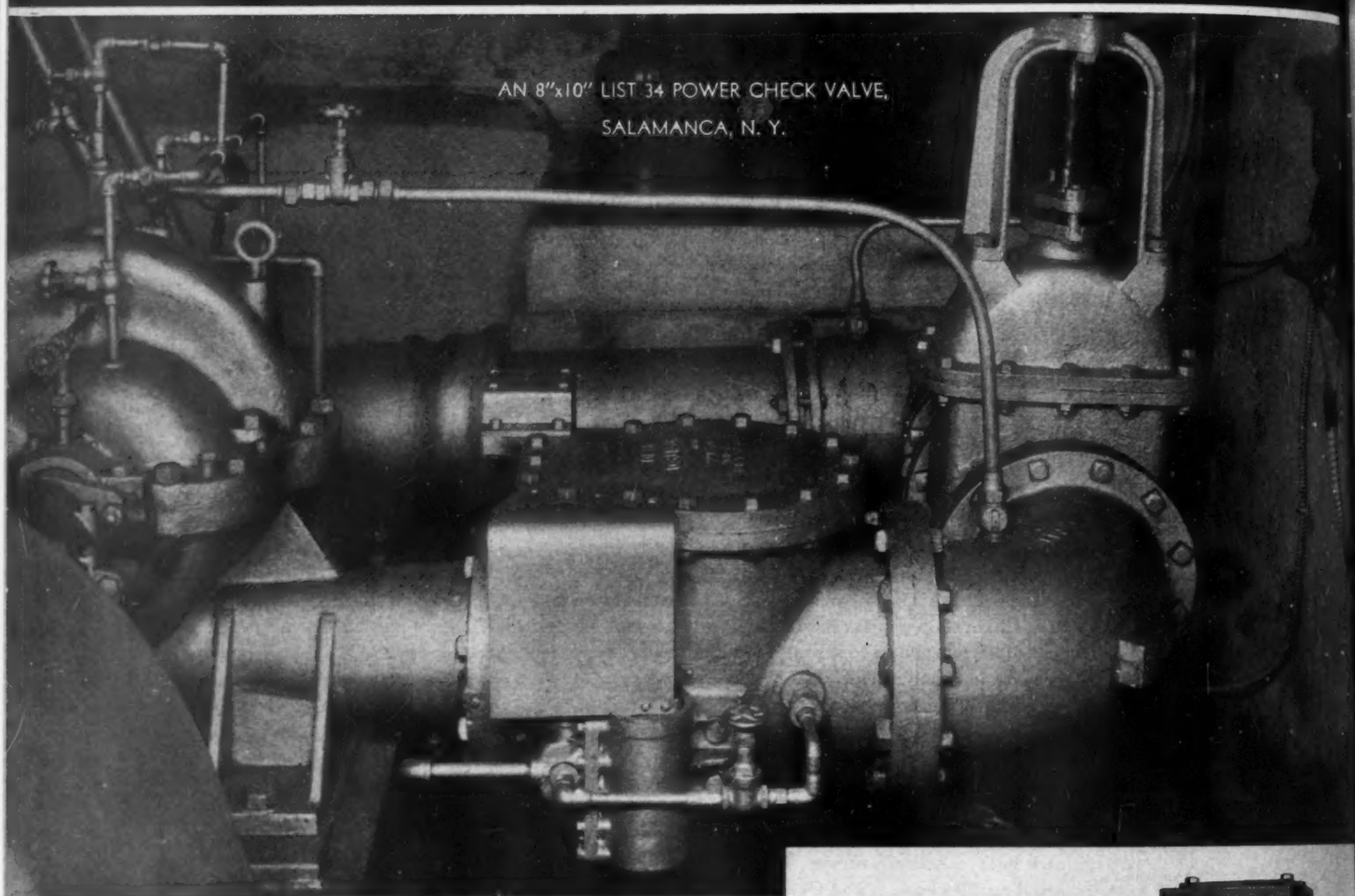

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WATER WORKS & SEWERAGE

E. S. GILLETTE, Publisher

L. H. ENSLOW, Editor

ARTICLES AND AUTHORS Scheduled for Future Issues

"A Sewer Rental Plan"—described and discussed by Robert A. Allton, Design and Consulting Engineer, Div. of Sewage Treatment, Columbus, Ohio, is a presentation of the meat of the new Sewer Rental Ordinance of Columbus. Mr. Allton tells of the several considerations incident to the development of an equitable and sound sewer rental plan and procedure in making charges and collecting the fees. The study made of various tried, and proposed, schemes of financing operation and maintenance of treatment works, led the Columbus authorities to adopt the scheme of charging on the basis of water billings, with collections made by the Water Department on a participating basis in respect to collections. Considerations given the method of charging for industrial sewage are of especial interest as is the language of the Columbus Ordinance, designed to prevent loop-holes, "special considerations," and "arguments" with the industrial sewer user over billings. This "sewage-tight" ordinance of Columbus should prove a worthy guide to the many confronted with the problem of financing sewerage developments and plant operation. (Originally planned for this issue, we regret that subsequent developments have necessitated holding it for our next issue.—Ed.)

"Putting the 'Water Works G-Man' to Work"—is the caption of an intriguing story by Roger Esty, Superintendent of Water at Danvers, Mass. This interesting story, from one of America's No. 1 water-works managers, reveals many unknown secrets of the water consumer, as recorded by Esty's "G-Men." His sleuths are the never sleeping and all-seeing "Meter-Masters" which Danvers Water Department has employed in a variety of ways to reveal a variety of **"little known** facts about **well known** consumers." These "G-Men," as Esty has christened them, see no evil; hear no evil; speak no evil. Being strictly a "mechanical-eye" and not subject to injecting any personal element in the matter of good consumer relations, their story in red ink is written without prejudice, fear or favor. The consumer and the manager know these facts so well that when the two meet, with the chart record of the robot "G-Man" on the table before them, the evidence presented proves a clean cut impersonal means of settling controversy, and disposing of hard to collect bills. More than this, the "G-Men of Danvers" have revealed a method of saving water works funds or collecting more revenue from metered services, faced with a charge of deficient meterization by Esty's mechanical sleuths.

"Sludge Incineration"—by E. T. Killam, Consulting Engineer, New York City, is a review of the trends in the direction of complete disposal of sewage solids by incineration, alone or in combination with garbage and rubbish destruction. Important recent sludge incinerator installations, with their especial features and capacities, are briefly described and the basic consideration in sludge garbage-incineration, with power development possibilities, are discussed. It constitutes a timely review of progress with a method which for the first time seems to completely solve the age-old sludge problem.

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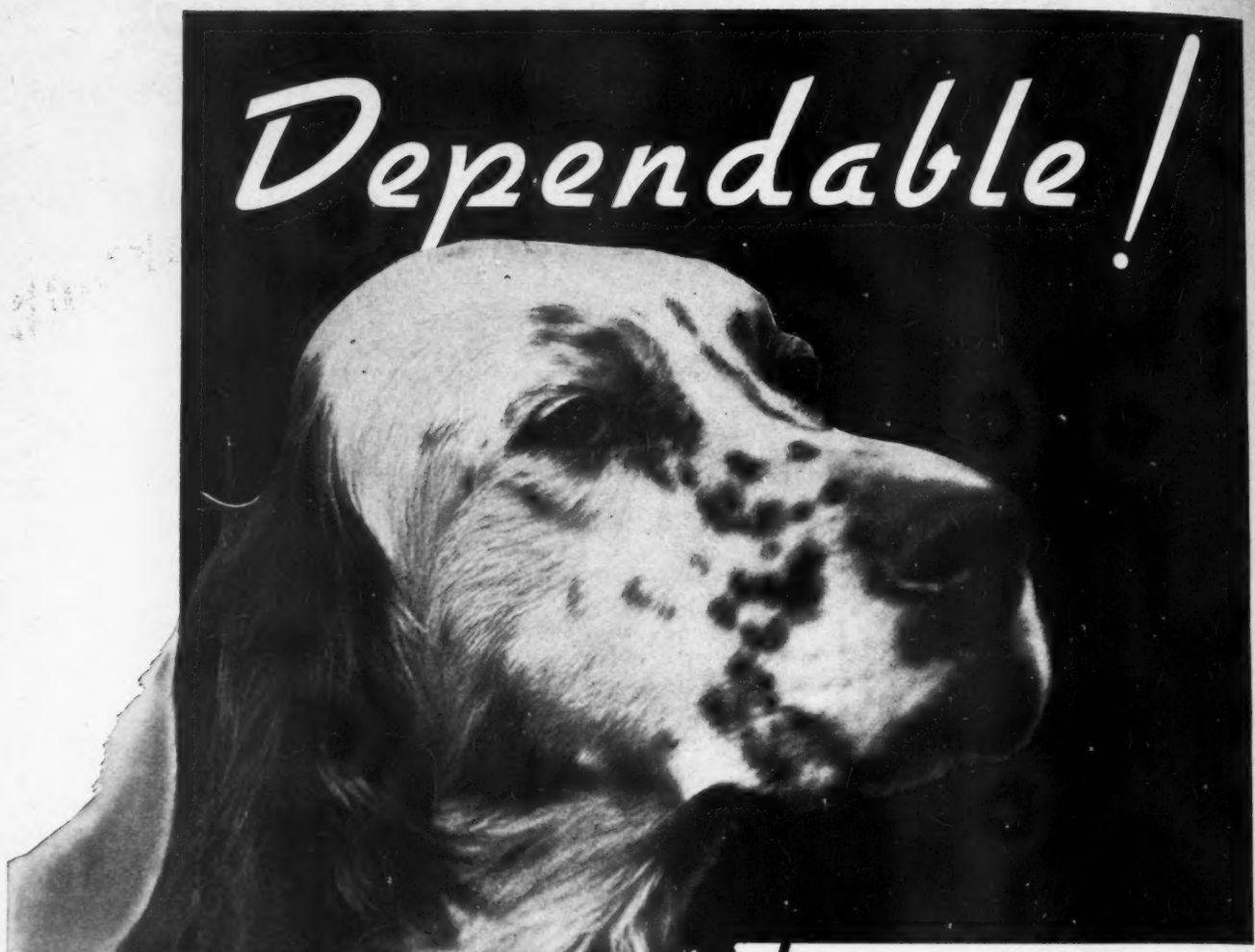

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WATER WORKS AND SEWERAGE
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VOL. 85 APRIL, 1938 No. 4

THE WATER WORKS AND SEWERAGE OF NEW ORLEANS

Some Unusual Features of Its Water Supply and Drainage Systems

By ALF. F. THEARD

General Superintendent,
Sewerage and Water Board,
New Orleans, La.

PREVIOUS to 1880, we find very little evidence of any fruitful attempt, from the engineering standpoint, to develop our great City of New Orleans, although it had been founded since 1718. Its death rate was 28.6 per thousand and its reputation was not the best, due to its unsanitary conditions, lack of drainage, sewerage, and an adequate water supply, and dangers of yellow fever epidemics.

The Author (A 44-Year Service Record)*

At or about that time (1880), an effort was made to start its sanitary improvements. The old waterworks company began the installation of filters, and the municipal authorities granted a franchise to a private corporation for the installation of a system of sanitary sewers. A little later, a serious movement was started for the building of a drainage system which culminated in 1893 in the organizing of a force under guidance of the City Engineer to make a complete topographical survey of the City of New Orleans and to gather the data necessary to the formulation of a complete modern system of drainage.

It was the first topographical survey of the city, and it gave valuable information. It was made under the direction of City Engineer Linus W. Brown, and an advisory committee of eminent engineers of high reputation, Messrs. B. M. Harrod, Henry B. Richardson, and Rudolf Hering. This survey gave to the city the foundation for the projecting of all of its future sanitary works, the greater portion of which have now been completed.

Up to that time, it was deemed sufficient to adopt makeshifts, one after another, to accomplish some immediate ends, and to benefit small disconnected sections. The result had naturally been a somewhat incoherent and crude system of drains and canals, insufficient in size, depth, and slope; a disposal of the water through main channels and outfalls objectionably located; inefficient methods of pumping; in fact, a bad system, based on erroneous information or no information at all.

It was evident that New Orleans was steadily advancing in size and importance, and that means had to be made available in proportion to its growth, to better its streets, its railway service, its lighting and water supply, its pavements, its sewerage, its drainage, and its general sanitary condition. This had to be based on well digested plans, designed to provide for future development. This first topographical survey supplied the initial information.

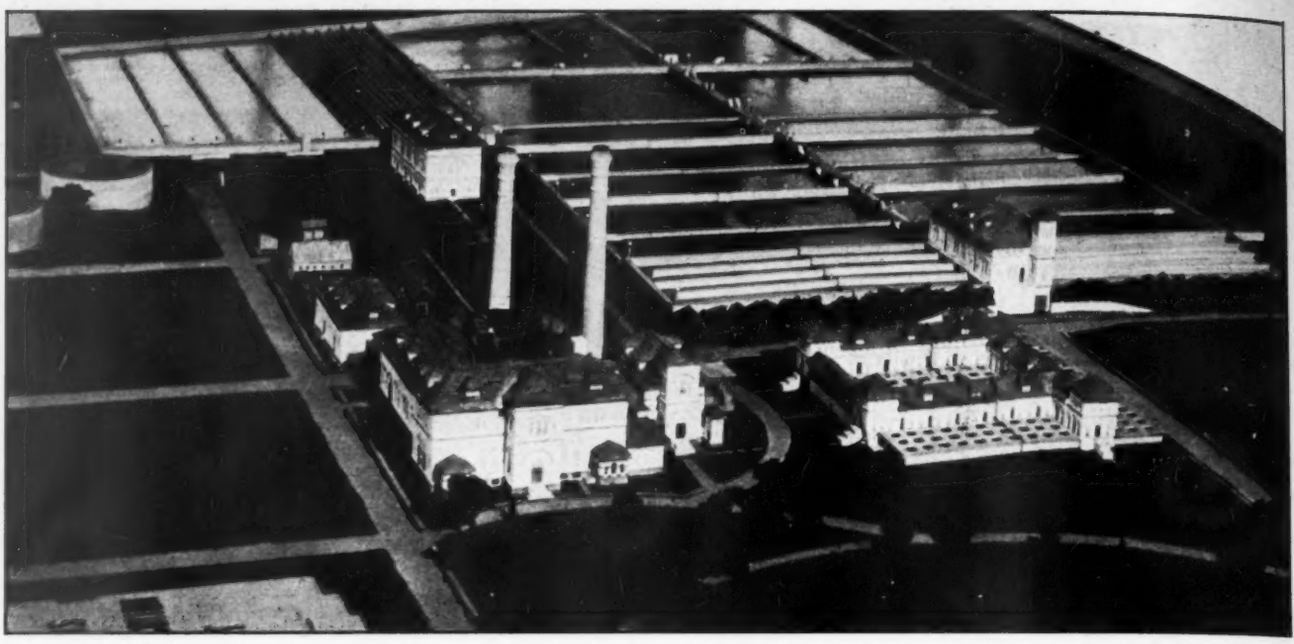
It was my good fortune to be connected with this preliminary work of importance as chief draftsman, and to have continued uninterruptedly my professional connection with the formulating of plans, and construction of the sanitary systems of New Orleans during these forty-four years. This has made the building of these great public improvements practically my life's work. As my personal efforts and professional services have been devoted to my employers, I am going to review, briefly, the progress of the construction work completed, to date, by the Sewerage and Water Board. This is the agency, through its distinguished officers, which had official charge of the expenditure of the funds dedicated to the construction of modern drainage, sewerage and water systems for New Orleans.

Sewerage and Water Board Created

The original body, the Drainage Commission of New Orleans, was created by legislative enactment in 1896, and, with a limited bond issue, was authorized to build a drainage system for the city. Subsequently, the city petitioned for and obtained the creation of the Sewerage and Water Board, providing it with a continuing tax for the construction and extension of the drainage, sewerage, and water systems, with an authorized bond issue of some twelve million dollars.

This new body absorbed the Drainage Commission and subsequently found itself in a position to increase its bond indebtedness to thirty million dollars. It continued to advance the construction of the sanitary im-

*The author of this article, starting with the Sewerage and Water Board of New Orleans as Chief Draftsman, attained his present position during a 44-year service record.



The Power Plant, Pumping Station, Settling Basins and Filtration Plant of New Orleans. Here Power is Generated for Pumping Water, Sewage and Drainage Station Operations. The Filter Plant Converts the Roily Mississippi Waters into Something Fit to Drink.

provements, and, today, with a total expenditure of some seventy million dollars, the city has over 804 miles of water mains, reaching about 99 per cent of the premises of the city with domestic supply and fire protection; over 698 miles of sewers, reaching about 96 per cent of the premises of the city with a sanitary sewerage system; and over 910 miles of drainage canals and pipe lines giving drainage, proportionate in its perfection to the development of the areas served, to the entire area within levees (about 50,000 acres), with a population of over 500,000.

Storm Water and Sewage Easily Separated

In the solution of these sanitary problems, it became evident to the engineers that a separate system of storm and sanitary sewers would be economical and desirable. This policy became highly important in all future design and construction.

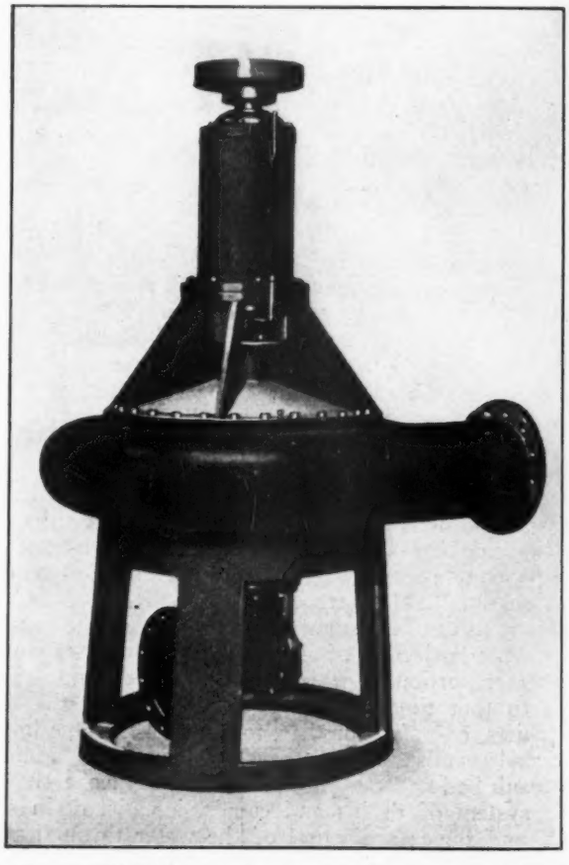
The storm waters must be handled through very large arteries, due to the extraordinary tropical rainfalls (sometimes 3 to 9 inches in 24 hours, and once 14 inches in 18 hours) and the size of the territory served, and pumped into tide level outlets north of the city with a lift of from 5 to 15 feet.

The sewage, it was found, could be handled through comparatively small conduits and must be discharged at a point below the center of the city into the Mississippi River against a head varying from 35 to 100 feet, including friction in the discharge mains.

In the design of its sewerage system, no startling or novel departures have been employed or attempted by New Orleans. Well known and accepted principles, such as have stood the test of years of practical use and operation, have been the basis. Fixing the territory to be covered in the plan; the present and future population; the probable varying densities of such population in different portions of the city; the probable amount of sewage, both from house sewage and ground water, to be taken care of; these important factors were combined and reduced to a convenient form for the determination of the general plan and the size of sewers required for different areas.

It is impossible, in this article, to go into a full detailed description of the sanitary sewer system; only the important features will be touched upon.

For all large areas of 2,000 acres or more, 62½ per cent of the total run-off of house sewage and full run-off of ground water was assumed, such being about 1,000,000 gallons per square mile of seepage. Areas of 200 acres or less were assumed to have full run-off of both house



The Famous Wood Trash Pump Developed in New Orleans for Sewage Pumping. Capacity 4,000 Gallons per Minute.

sewage and ground water. Population is estimated at 50 per acre for ordinary residential areas, and up to 115 per acre in dense business sections.

The unit of the system is an eight-inch pipe (probably 87 per cent of the total mileage of the system) increasing in size to the largest circular main built of brick, and having an inside diameter of 7 feet. Where natural conditions contribute so little to grades, it was decided to fix a minimum slope of one foot in 450 feet for an eight-inch sewer, and the bulk of the sewer system is designed to that grade. With an initial velocity of two feet per second in the laterals, the velocity is gradually accelerated, increasing with the size of the sewer, until it reaches over 3.5 feet per second in the largest mains. Recognizing the importance of flushing, flush tanks are usually not left to automatic flushing, but are flushed several times in quick succession, two or three times a year. However, house flow and ground water take care of this pretty well.

The Famous Wood Pump Developed

The question of transportation of sewage in such flat graded sewers and for such long distances, to its ultimate point of disposal, necessitated the construction of intermediate pumping stations. For these intermediate lift stations, which must be in operation twenty-four hours each day, the question of attendance, screening of sewage, and also the removal of screenings, had to be met or eliminated.

A design for a centrifugal pump was worked out by A. B. Wood, Mechanical Engineer of the Sewerage and Water Board, which could pass any object which entered it, and would pass a 12-inch ball or any amount of water carrying flexible trash, rags, etc., without obstruction or decrease in efficiency. [This has since become an important contribution of New Orleans to the sewerage and drainage world.—Ed.]

The impeller of the Wood Trash Pump was essentially different from the impellers in the other existing centrifugal pumps, and enabled it to handle coarse unscreened sewage or other stringy or bulky material without clogging. The impeller was of the enclosed side suction type. The water-ways through the impeller were well filleted and rounded, (forming extremely smooth contours devoid of sharp corners) so as to prevent rags and stringy or fibrous material from catching or clogging while passing through the parts. Any material going through the suction opening would pass through the pump without catching. The volute casing was close grained cast iron of extra thickness, to withstand the severe wear. A heavy side plate was bolted to each side of the volute. The shaft was an exceptionally heavy steel forging. The bearings in the horizontal pump are of two types, ball bearing and self-aligning sleeve bearing. Both are outside the pump and not in danger of being affected by water or material passing through the pump.

The sewage lift stations were equipped with this type of centrifugal pump, automatically operated without cost of attendance or nuisance of screening, or removing of screenings, and their operation proved entirely successful. The final point of disposal is into the river below the center of the city. Mixed with even the minimum discharge of about 200,000 cubic feet per second of the muddy Mississippi River waters, the sewage, thus amply diluted and borne down stream from the city, has never proved offensive nor can it be considered dangerous to health.

Inside the World's Largest Drainage Station. Pumping Station No. 6. Capacity 6,250 sec. ft., or 168,750,000 Gallons per Hour at Twelve-Foot Lift. The Four Pumps in the Foreground Are 14-foot Wood Screw Pumps; Capacity 1,000 Cubic Feet Per Second Each.

New Orleans Drainage of Yesterday. (Melpomene Drainage Pumping Station.) This Steam Powered Station Had a Maximum Capacity of 150 Cubic Feet Per Second with a Lift of 5 Feet. The Station Had Only One Paddled Wheel; Diameter 35 Feet, and Paddle Face of 4 Ft. 6 In. The Idea Must Have Come From the River-Boats.

The Water Works System

Of the water supply system the following description can be given:

There is a river low lift pumping station to force water from the river through the twin 48-inch pipe lines, 4,000 feet long, to deliver it to the purification plant in times of very low water in the river.

The first step in purification is the removal of the heavier particles which will settle out promptly by passage at a very low velocity through grit chambers. Then lime and sulphate of iron are added and automatically proportioned to the amount of water being treated, as it is passed, at a sufficient velocity to prevent deposit and promote effective mixing, through about a mile of mixing passages.

Leaving the mixing passages, with the necessary reactions completed, the water passes into and through the settling basins where nearly all of the suspended matter and bacteria, originally carried, and much of the carbonates of lime and magnesia, originally in solution, as well as the coagulated chemicals, are deposited. From these basins, the water passes to the filters, which are of the rapid gravity sand type, and then receives ammonia and chlorine treatment.

Partial softening, coagulation and filtration, since 1909, have purified the water of the very muddy Mississippi, containing an average of 660 parts per million of very fine suspended matter, and 2,500 bacteria per cubic centimeter, giving to New Orleans a soft non-corrosive supply of clear water, complying fully with the rigid tests of the United States Public Health Service as to its sanitary quality.

After filtration, the water is delivered to the distribution system by direct pressure pumps, or sent to the clear water storage reservoirs by low lift pumps for future delivery to the distribution system. Seventy pounds pressure is maintained at the Water Works Pumping Station and usually not less than 60 pounds pressure is shown at remote points on the distribution system.

The former capacity of the Water Purification Plant was 40,000,000 gallons per day, but this has been increased to 112,000,000 gallons per day to afford a reserve capacity and to meet future demands.

Drainage System

There are ten drainage stations equipped with pumps varying in type from centrifugal to screw pumps, with horizontal or vertical shaft, of different makes and capacity, some submerged and others not, with a total pumping capacity of 27,000 cubic feet per second, all electrically operated, mostly from the Water Works Pumping and Power Station, where there are now available 35,000 horse power of electric generators.

The unit of the drainage system was fixed at a 10-inch pipe with a slope, when obtainable, of one foot in three hundred feet, to take care of the run-off of about one-third of an acre, and the rate of run-off was fixed at 20 to 80 per cent of the rainfall for suburban and improved areas, respectively.

In our spongy soil the rate of run-off varies materially, such being affected by weather conditions (drouth or rain) which precedes any rainfall. Especially is this the case in the unimproved sections, and this factor was an essential one to be considered in fixing the ultimate size of the large arteries built to serve each area. A minimum slope of one foot in 2,500 feet was fixed for all large canals.

Due to our special conditions of run-off and rainfall, the requirements of pumping installations for drainage are for very large capacities at comparatively low and varying heads; the practice commonly being to pump from one water level on the suction side to a higher level on the discharge side, the difference in levels varying frequently from a maximum of 17 feet down to zero.

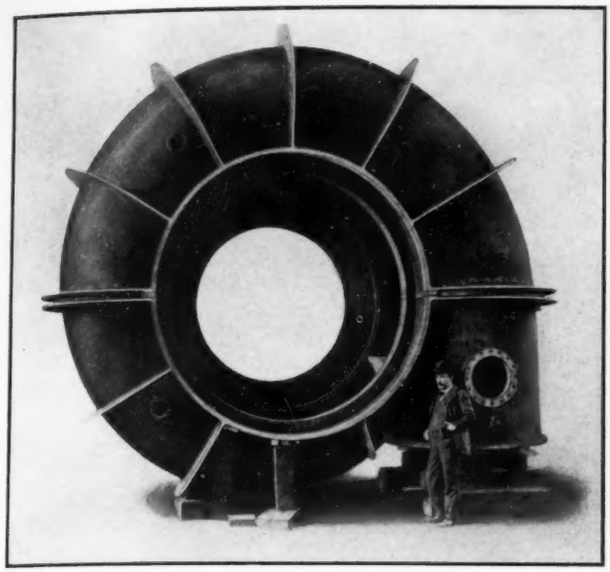
Wood's Screw Pumps Developed

The Wood Screw Pumps were also designed by A. B. Wood, Mechanical Engineer of the Sewerage and Water Board of New Orleans, and these gigantic and successful pumps are installed in the six different drainage stations in the city.

The general engineering features connected with the drainage of New Orleans are well known to the engineering profession. We require pumping machinery with an aggregate capacity far in excess of any other pumping system in existence. The problem was to secure pumping units which would show the following: reliability of operation; reasonable cost of pumps proper; cheap cost of buildings, foundations, and basins; fair cost of motors to drive pumps; low cost of required prime mover capacity, generators, and transmission lines; and economy of operation of system.

The Wood Pumps proved the solution of these problems. The New Orleans units are free from vibration, they operate at high speeds, and are connected to electric

One of New Orlean's Finest—1898. *(The Dublin Street Drainage Station.) This Station Had a Maximum Capacity to Deliver 480 Cubic Feet of Water Per Second with a Lift of Five Feet. Inside Were Twin Paddle Wheels 34 Ft. in Diameter and Paddle Face of 6 Ft. Driven by Steam Engines.*



The Coming of the Centrifugal. Centrifugal Pump Installed by the Drainage Commission about 1899. *.Six-Foot Discharge, Electrically Driven, Capacity 250 cubic feet per Second. Seemed an Improvement over the Water-Pushing 35 ft. Paddle Wheels.*

motors at constant speed. These pumps consist of cylindrical castings, with their axis horizontal, containing the impeller and diffuser rings or stationary blades, with suitable provision inside the pump for preventing sudden changes in velocity of the water. In size they are 12 feet in diameter of pump case; the discharge pipe outlets being 15 feet in diameter at the point of maximum area. Tests at a lift of 7½ feet have shown an efficiency of 76 to 80 per cent.

In brief, the design consists of a siphon, in the summit of which a screw type impeller of patented design rotates. The casing is split horizontally so as to facilitate access to the interior of the pump. The impeller is fitted with steel blades carefully shaped and finished and securely held in the hub of the impeller. The pumps are placed at the summit of a pipe siphon, and pipe connections are made to the suction and discharge canals without the intervention of any valves or gates. Priming is accomplished by means of rotary (wet vacuum) pumps. By admitting air to the case before stopping the pump, the vacuum is broken and the water prevented from siphoning back into the suction basin.

New Orleans, with its levee enclosed area of 50,000 acres, is subject to an annual rainfall of 56 inches, with a record of 14 inches in 18 hours, and requires an unusual pumping capacity to meet such conditions. This has prompted me to give the brief description of our drainage pumps.

Assets and Liabilities

With its tax of 2 mills on real property, and a total bond issue of $30,000,000, of which only $24,000,000 are now outstanding, the Sewerage and Water Board of New Orleans has assets of $70,000,000 represented by $26,000,000 of water extensions, $25,000,000 of drainage work, and $19,000,000 of sanitary sewer system.

The nature of the soil of New Orleans is one of the most extraordinary combination of various formations found anywhere. Under a cover of river sand, deposited there by the floods of the river before the building of protection levees, the territory next to the river is a series of strata varying from blue clay to quicksand, with no fixed order of depth, class, or thickness. The balance of the territory on the east bank, which commences at a point from 5,000 to 6,000 feet from the river, was formerly a swamp with its surface practically level. It is made up of a large percentage of decayed vegetable matter, or a mixture of peat and muck. Peat is partially decomposed vegetable matter, while muck has a considerable percentage of silt, clay and sand mixed with well decayed matter.

Quicksand, in New Orleans, is composed of the very finest particles of rounded sand which will flow freely through the smallest openings whenever there is an excess of water (and the least bit of pressure) to carry them. The alluvial formation of the soil, by overflow from the Mississippi River, accounts for the extreme fineness of all of this sand, all of the coarser particles have been sorted out and deposited by the river long before it reached New Orleans.

In such sponge-like soils, subject to an absorption of a large percentage of ground or seepage water, such quicksand creates unusual difficulties, the more so when a trench is excavated in an undrained area. But it is so even in areas which, due to open canals and improvements, have had the ground water line reduced.

Construction Problems

I recall that in the central area, where improvements had already lowered the moisture line, we were called upon to install a large reinforced concrete canal, some 12 to 25 feet wide, with all of its branches and connections. While our work was progressing about one mile from the river, we happened to cross a vein or stratum of quicksand, just about the period of the year when the Mississippi River was at its highest stage. This vein of quicksand down in the trench was approximately 20 feet below the level of the water in the river. No pumping could keep ahead of the flow into the trench. It was finally decided to concentrate the flow through a small barrel head connected to the trough carrying this flow of water some distance away. By careful attention, the reinforced concrete bottom was poured around this barrel head and, after full set, this was plugged and the hole was concreted over, leaving the water to continue flowing where it did before. This work, executed 20 years ago, was effective, for there had been no further trouble at this point.

Often, when sheeting or sheet piling is driven to protect the trenches, signs of sloughing below our bottom rangers develop. We pump out and fill the pit with a cheap grade of concrete. But one of the most troublesome questions to solve has been to prevent settlement or subsidence over the backfilled trench after the work is done.

The original design of the storm sewers provided a substantial space between the sidewalls and the sheet-piling. This space had to be backfilled after completion of the work. While the specifications provided for careful backfilling, we have reached the conclusion that the tamping or ramming of local clay back filling is utterly futile. The flooding of such backfilling, to compact it, is worse than futile.

A New Method Devised

With this special problem in mind, at the time that it was my good fortune to be placed in charge of drainage construction work, a new method of construction was devised to eliminate the troublesome space back of the canal walls.

This new section has many advantages. It is true that the wooden sheeting left in the trench must be abandoned, but the width of excavated trench is reduced, and this eliminates completely the chance of any subsidence

New Orleans Drainage of Today: Pumping Station No. 6 (The Largest in the World) Capacity—6,250 Sec. Ft. of 168,750,000 Gallons Per Hour, at 12 Foot Lift.

due to backfilling. This has been found so satisfactory, that no suggestions have as yet been advanced for a change in methods of construction.

Selection of Pipe Materials

Vitrified clay pipe had been in use for all subsidiary drains up to the year 1917. At or about that time, the concrete pipe manufacturers asked to be given a chance to compete, provided tests of concrete pipe would prove satisfactory. As an enthusiastic partisan towards all concrete products, I was very glad to have our office get the opportunity to conduct these tests. The results were eminently satisfactory, so much so that the specifications were prepared fixing the requirements for concrete pipe, and these were included in the regular specifications, giving the city the right to select either vitrified clay or concrete pipe for all contract work. Since then, concrete has been given the preference for large pipes.

But, all the time that concrete has been rapidly improving and gaining support, the manufactures of vitrified clay pipe have made such improvements in the manufacture of this class of pipe that it stands, certainly, today, as a more than serious competitor with concrete pipe, due to its smoothness, its strength, and its general true cast.

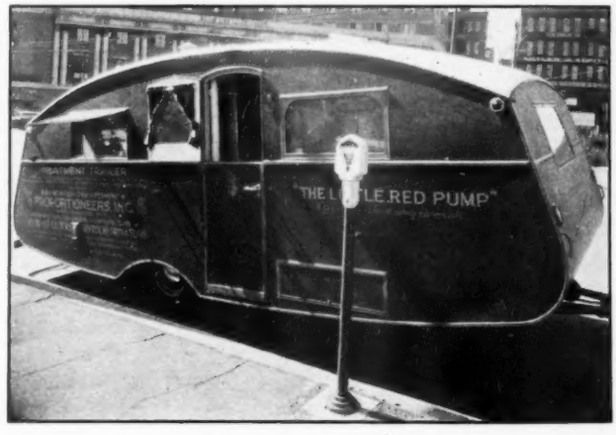
With it all, the construction of our great sanitary systems has progressed and New Orleans is fast taking its rank with the large modern cities. Its death rate has been reduced to 14.72 per thousand; its commercial development has been phenomenal; its population has increased to over 500,000, or nearly 100 per cent in 40 years, and its splendid location, port, and airport facilities have advanced it to the rank of second port of the United States.

This month, April, 1938, we are entertaining within the gates of this historic metropolis the American Water Works Association, which has done us the honor of selecting New Orleans as its convention place. The membership of this organization will find that the water supply and sewerage facilities have been vastly improved in the period since its last meeting in this unique city where considerably more water must be pumped out than is pumped in.

"AND IN ITS PLACE A MIGHTIER OAK GREW"

In our issue of November 1937 under caption "The End of the Trail," we told the sad story of Proportioneers' Treatment Trailer, I which "went west" when it became uncoupled on U. S. Highway No. 1 and did the impossible thing of trying to "Mow 'em down!" We refer to the poles of A. T. & T. Co. along the side of the road.

Then came the settlement with the insurance company; and now in its place "a mightier oak has grown"



Treatment Trailer—II

in the form of "Treatment Trailer II" here pictured. The new edition of Proportioneers' Treatment Trailer, more pretentious and spacious than the first, will be used for the same purpose—that of taking Proportioneers' Chemical Feeding (Proportioning) Equipment to the door steps of water and sewage plants, swimming pools, industrial plants, health departments and consulting engineers, and to meetings and conventions, for educational and sales purposes.

This year Mr. Corydon, who piloted "Treatment Trailer I," over many miles of U. S. highway through various states, will be "spelled" by his associate, Mr. Armbrust, their first destination being the A.W.W.A. Convention in New Orleans.

WATER SUPPLY BETTERMENTS AT NEWPORT NEWS, VA.

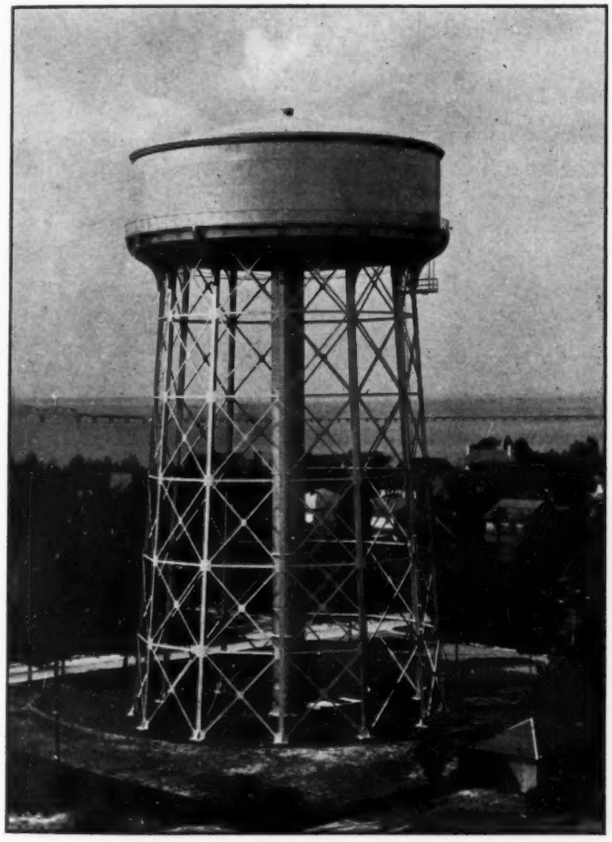
By EUGENE F. DUGGER

Gen'l Manager, Water Works Commission, Newport News, Va.

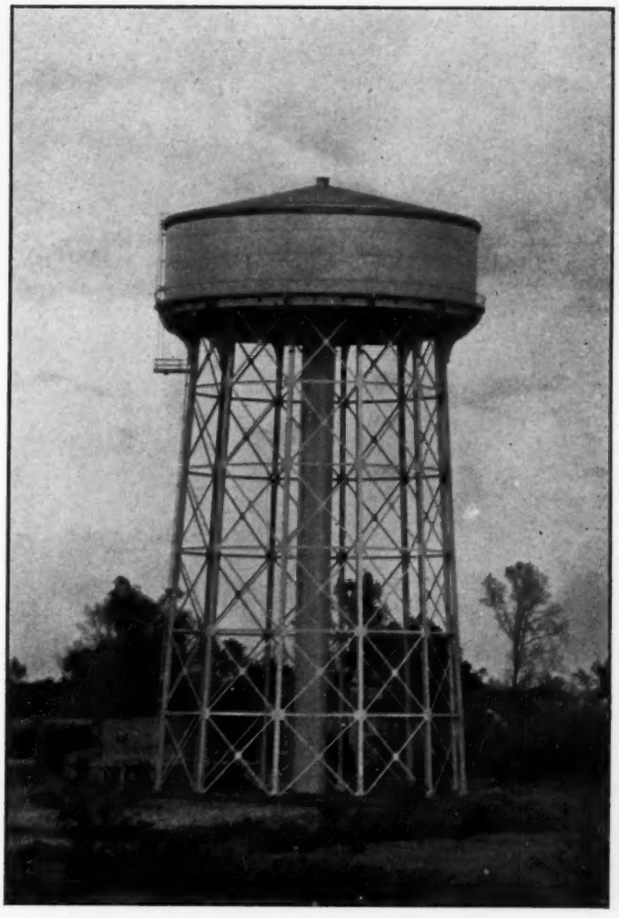
*The Author**

THE Newport News Waterworks which supplies practically all of the built up portions of the Virginia Peninsula south of Williamsburg has been owned and operated by the City of Newport News since 1926. The daily average pumpage of about 4,300,000 gallons supplies a population of about 70,000. The system is essentially 100 per cent metered.

The normal source of supply is from an impounding reservoir at Lee Hall where it is filtered and pumped through parallel mains to Newport News, a distance of about 14 miles. The distribution system extends through Newport News to Hampton, Phoebus, Old Point Comfort and Buckroe Beach for a distance of about 10 miles. Reserve reservoirs are situated at Harwood's Mill and Skiff's Creek. There is a booster station near the north city limit of Newport News.



Newport News' No. 1 Tank. Located in the West End. Provides Elevated Storage of 1,000,000 Gals. (For Pressure Results See Charts.)



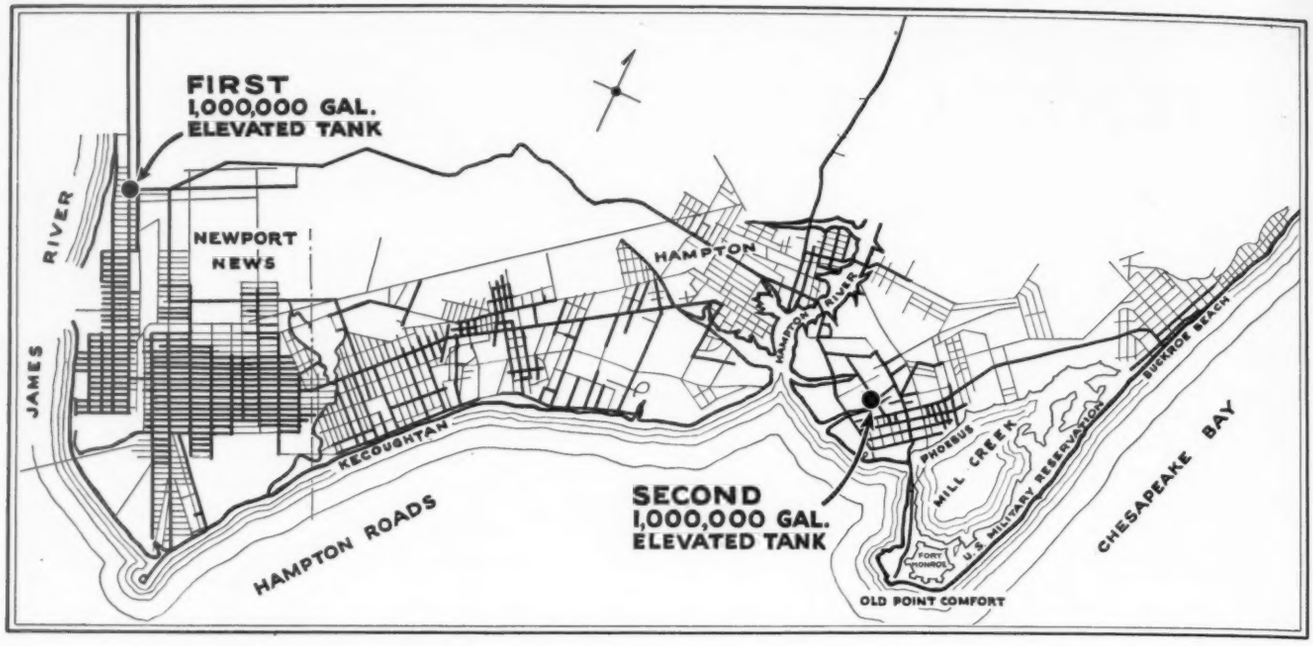
Newport News Gets Twin of Its No. 1 Tank for East End, and Adds Another 1,000,000 Gals of Elevated Storage. (For Pressure Results See Charts.)

Some History

Prior to 1926 the system was privately owned and operated, being established in 1889. The original system was reinforced in 1919, but not until after the purchase by the city in 1929, were any major improvements made. However, the year 1929 seems to have been the beginning of a new and better era for the Newport News Waterworks. Since that time quite a number of major improvements have been made.

About 4.1 miles of one of the main supply lines from the Lee Hall Pumping Station was of 20-inch wood stave. This main has all been replaced by 30-inch cast-iron pipe. During the existence of the wood stave line a number of breaks were experienced and consequently its replacements by 30-inch cast-iron is seen as a distinct improvement.

**The author of this paper is completing a highly successful term as President of the American Water Works Association, during which much to his credit has been accomplished.—Ed.*



The Newport News System, Showing Locations of Mains and New Elevated Tanks.

In 1929 and 1930 two 5,000,000-gallon electrically driven centrifugal pumps were installed at the booster station just inside the city limits. These pumps take suction from the supply mains and a 3,500,000-gallon concrete reservoir. At Harwoods' Mill Reservoir, one of the reserve reservoirs, three 5,000,000-gallon semi-diesel operated pumps were installed; and 7,700 ft. of 30-in. cast-iron pipe was laid from the pumping station at Harwood's Mill over the southwesterly summit of the Lee Hall watershed to the main stream supplying Lee Hall Reservoir. This installation permitted a daily pumpage of 5,500,000 gallons during the dry summer of 1930 to augment the depleting supply at Lee Hall Reservoir, thereby increasing the reliability of the system. At this time the coagulation basin at the filter plant was increased to double its former size.

More Recent Improvements

In the period 1934 through 1936 the above mentioned replacement of the 20-in. wood-stave line by 30-in. cast-iron was completed. Then, also 4,200 ft. of 16-in. cast-iron pipe was laid in the western side of Newport News, as recommended by the National Board of Fire Underwriters. This installation vastly improved fire protection and stabilized pressures to a large measure. The Lee Hall Pumping Station was then electrified and two 1,000,000-gallon elevated tanks were installed. The total cost of these improvements over a period of seven years, exclusive of other work, has been about $485,000. The cost of this work does not begin, however, to compare with the benefits derived therefrom.

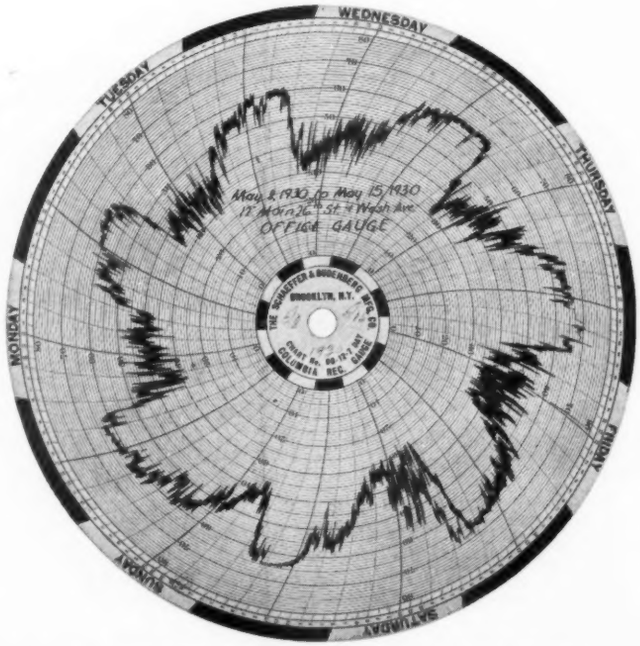
Results from Elevated Tanks

Perhaps the most interesting of these installations is that of the two 1,000,000-gallon elevated steel tanks and the results obtained therefrom. These two tanks were designed and erected by the Chicago Bridge and Iron Works. The height to the bottom of each tank is 125 feet. The shells are 84 ft. in diameter and have a depth of 25 feet.

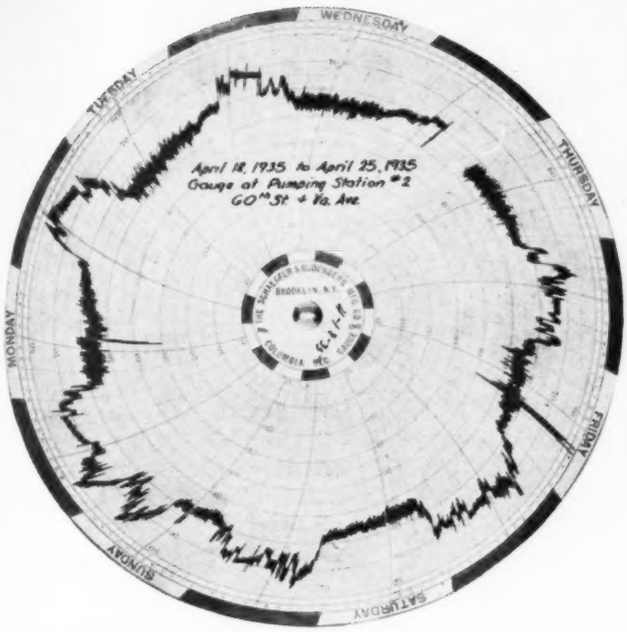
The danger of breaks in the main supply lines and the remoteness of the supply make this type of installation, to provide gravity pressure reserves, quite desirable.

The tanks are located as shown on the accompanying sketch-map. The first one is located near the north city limits of Newport News in the eastern extreme of the distribution system. The other tank is located in Phoebus, in the extreme western portion of the distribution system. These tanks remain at least half full at all times, consequently a uniform pressure is maintained throughout the entire system.

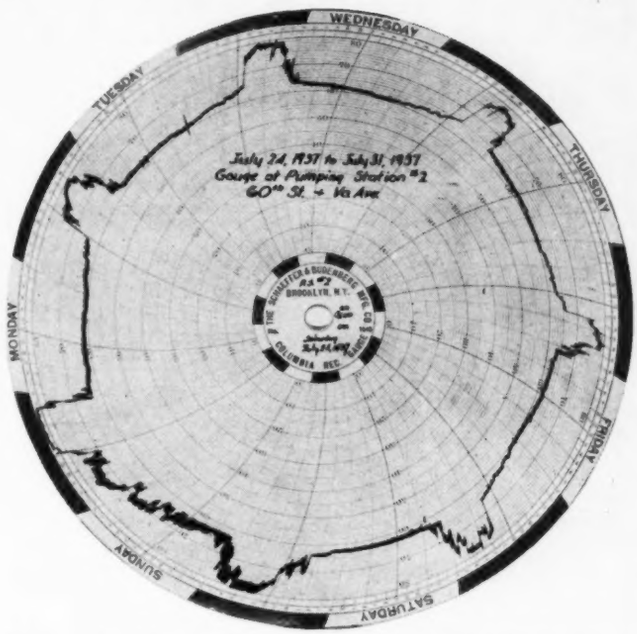
Prior to the installation of the tanks recording gauges showed variations in pressure of from 30 to 70 pounds per square inch, also wide fluctuations in short periods of time. However, since the installation of the tanks pressures have been more nearly constant with a maximum variation of from 50 to 70 pounds per square inch. The daily average pressure is about 58 pounds per square inch with only slight variations. The accompanying pressure-record charts tell their own story with respect to the benefits of the two new tanks.



Pressure for 1 Week Before Installation of Tanks.



Pressure for 1 Week After Installation of Tanks.



Pressure for 1 Week Since Installation of Second Tank and 16-In. Main.

It is easy to understand how, with these uniform pressures and gravity pressure reserves, the fire protection and the service of the whole system is materially improved. The installation of the tanks has also permitted a more uniform rate of pumpage, which has reduced day in and day out pumpage costs. Since the installation of the tanks and electrification of the Main Pumping Station the cost of operation of the pumping and filter plant has been reduced by ten per cent.

Although there still is and always will be room for improvement, the work done to improve the Newport News water supply system in the past few years has certainly made for its greater efficiency and established reliability.

The author desires to express his appreciation to Mr. W. S. Grant, Office Engineer, for his assistance in the preparation of this paper.

▼

ROGER ESTY NEW A.W.W.A. DIRECTOR

Roger Esty

At a recent meeting of the New England Section of A.W.W.A., Roger Esty, Superintendent of Water Works, Danvers, Mass., was selected as Director of A.W.W.A. to succeed Robert Spurr Weston whose term expires at the close of the 1938 Convention, April 28th.

Mr. Esty is being sent to A.W.W.A.'s Board of Direction as a seasoned official. Not only is he one of the country's No. 1 water works managers, but he is a No. 1 citizen of Danvers; and, a "wheel-horse" in the New England Water Works Association, to the Presidency of which he went in 1935 in recognition of his many valuable and recognized services to that association.

New England has done well in its selection and A.W.W.A. will profit greatly by having the seasoned and capable Roger Esty as a member of its Board.

STEEL PIPE LINES FOR WATER SERVICE

(*A Report of the Underwriters' Laboratories, Inc.*)

"Steel Pipe Lines for Underground Water Service" is a bound report of 150 pages covering an investigation of steel pipe for water service lines, begun in 1936, which has just been released by the Underwriters' Laboratories, Inc.

The report presents basic facts relative to the suitability of steel pipe for underground water service. Manufacturing processes are reviewed and illustrated. Results of deflection and ductility tests of steel pipes, and Dresser Couplings, are revealed to show the advantageous qualities of such pipe and gasketed type couplings.

The "Service Record Investigation" reveals a generally favorable experience with steel pipe. Useful information is presented regarding internal and external protection of steel pipe lines against water and soil attack; the report pointing out, however, that in many soils special protective coatings for steel do not appear necessary.

Tables of wall thickness of steel pipe and correlative information are presented, as a guide in the selection of steel pipe for (a) transmission mains, and (b) distribution mains.

In this report and the several Appendices which follow it are presented statistical data and technical findings which have been responsible for the conclusion drawn from Underwriters' Investigation 888, to the effect that steel pipe properly designed and installed is a reliable means of conveying water underground. The new Underwriters' "Standard Specifications for Steel Pipe Lines" is enclosed with the report as a separate publication of 13 pages—along with added Appendices.

To our knowledge it is the first report on steel pipe for water mains that the Underwriters' have issued. Certainly, it is the first time that steel pipe for water service has been recognized to the extent that an Underwriter's specifications have been drawn and presented.

SEWERAGE FACILITIES HARD HIT BY SOUTHERN CALIFORNIA FLOOD

Effects of Flood of March 2, 1938, in the Counties of Los Angeles, Orange, San Bernardino and Riverside

By A. M. RAWN*
Associate Editor,
Los Angeles, California

A TWENTY-FOUR HOUR rainfall commencing Tuesday evening, March 1, 1938, brought four of the southern counties of California a storm which, in parts of the mountainous areas lying some fifty or sixty miles inland from the seacoast, constituted a precipitation record not expected to recur in the area for four or five hundred years. The short period intensity of the storm was not so great. Maximum precipitation for any one hour during the storm, will have a frequency occurrence of once in about fifteen years. Torrential rains are the rule rather than the exception along the seacoast of Southern California. Moisture-laden air masses which strike the coast at varying velocities, are forced upward by the cushioning effect of lower air lying between the sea and the mountains, cool rapidly and discharge their condensed moisture quickly. The result is heavy rainfall, usually increasing in intensity toward its ending. There is no precipitation from late spring to early winter, and drainage courses are usually dry for nine or ten months during each year.

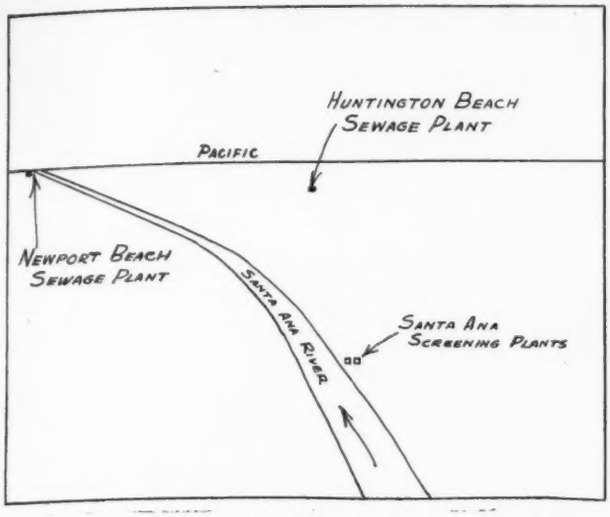
The Author

The heavy downpour of March 2nd was of such proportions as to overtax many of the flood control facilities, already constructed and to work havoc where improvements were built in or near original and long forgotten drainage courses. No survey could have located

*Assistant Chief Engr., Los Angeles County Sanitation Districts.

(Photo courtesy Watson Air Fotos, Inc., Long Beach, Calif.)

The Santa Ana Plays Havoc with Sewers and Three Plants in Orange County—Looking Down Stream to the Pacific; Note Two Breaks in Levees.



Guide as to Locations Inundated Sewage Plants Along the Santa Ana

the long unused water channels with greater accuracy than this storm which searched them out and left them marked by paths of ruin.

Along with washed-out highways and bridges, and undermined railways, and broken communication and electrical transmission lines,—sewers and sewage treatment plants came in for some pretty stiff jolts. Fortunately, public water supplies suffered but little, although precautions imposed following the storm were prompt and aimed at prevention of contaminated water use. Chlorination was stepped up in some instances and invoked in others where it had not been previously practiced. With much gratification, there has been no increase in the incidence of sewage contributing water borne diseases following the storm.

Los Angeles Sewers Go Out

Damage to the sewers of the City of Los Angeles was largely confined to lines parallel to or crossing the Los Angeles Flood Control Channel or its tributaries. In all, six crossings were damaged to the extent that sewage from Glendale and the San Fernando Valley cities was all discharging into the Los Angeles River. By March

A Los Angeles' Hyperion Screening Station. (A Picture of Another Flood—But Illustrative of with What Californians' Have to Cope, with the Advent of "Unusual Weather Conditions.")

A Washed Out Los Angeles Sewer (Glendale) Being Returned to Service by Using 36 In. Corrugated Iron Pipes. Note Sand Bagging Employed to Confine the Sewage Flow During Reconstruction.

Typical Scenes of March 3rd

Top: Manhole Geysers on Combined and Storm Sewers in Los Angeles System—This One Looks Fairly "Pure." Bottom: Los Angeles' Trunk Sewer Relieves Itself Through Vents and Manholes—Not So Pure

31 all crossings had been temporarily repaired and sewage again flowing to the City's treatment works. The City's Lankershim sewage pumping station was completely destroyed when the river cut far into its old banks, removing not only the plant but the plant site as well. The City's main screening plant at Hyperion (on the Pacific shore line) was undamaged and was never in peril because the North Outfall leading to the plant relieved itself by discharging through holes cut in the crown for ventilation purposes.

Sewage flow at Hyperion approximated 600 cubic feet per second, compared to an average daily peak of 300 c.f.s. Spouting manholes, broken river crossings and sewage flowing from vents in the outfall indicated that nowhere near the entire flow entering the sewers during the storm reached the plant. Such relief openings precluded a dangerous pressure build up on the lower sections of the main outfall sewer.

The Fate of the Two Screening Stations on Orange County Districts' Joint Outfall Sewer. (For Unfortunate Location See Air View of Flooded Santa Ana Valley.)

Damage to San Bernardino's Trickling Filters—March 3, 1938.

Digging Out San Bernardino's Sewage Pre-Chlorination Station on the Edge of the City. It Was This Station That Made It Possible to Disinfect the Sewage, Although the Outfall Was Out Beyond and the Plant Is Still Not Functioning at This Writing.

The activated sludge plant at Pasadena, the Joint Disposal Plant of the Los Angeles County Sanitation Districts, the trickling filters of Whittier, and the activated sludge plant of Pomona were all spared serious difficulty, partly because increase in flows to the plants during the storm was limited by the capacity of lines leading thereto and, in part, because the plants are so located as to escape the destructive work of overtaxed drainage channels. Damage to the collection lines leading to these plants was not serious although all were greatly overloaded during the storm. The Redlands sewage plant, situated in the wide wash near the junction of Plunge Creek and the Santa Ana River, escaped injury. The river here is wide and shallow and the Imhoff tanks were not undermined.

San Bernardino Plant Hard Hit

San Bernardino, through which flows Lytel Creek, a tributary of the Santa Ana, suffered to the extent that some 1500 feet of expensive 24-inch, 18-inch and 15-inch outfall leading to its trickling filter plant was destroyed when Lytel Creek got out of banks and flowed over the plant, washing out portions of the north and east walls (See picture), drowning machinery, covering the filters with silt to a depth of six inches and destroying sludge beds. Sewage from the city is now being concentrated near the plant (now undergoing rehabilitation) and is heavily chlorinated and discharged into Lytel Creek. The plant is expected to resume operation about April 15th.

Farther down its course, the Santa Ana River flowed over the small activated sludge works at Colton but did no damage other than to fill the tanks with debris. At Riverside, downstream from Colton, the city's septic tank and broad irrigation beds were entirely destroyed. In contemplation of a complete new sewerage system, including treatment works, it is probable that Riverside sewage will be treated only to a minimum extent, requisite with health requirements, pending new construction.

Santa Ana Wrecks Orange County Plants

Some fifteen miles below Riverside the river cuts through a pass in the Santa Ana Mountains and then widens out onto the flat coastal plain. Between the mountains and the sea lie Fullerton, Anaheim, Santa Ana, Orange and a number of smaller towns. All of these cities have cooperated in the construction of the Orange County Cities' Joint Outfall sewer. Sewage from the entire area flows southerly in trunks and intercepters to a junction about three miles southwest of Santa Ana, where the District had erected two screening stations. From these stations the outfall sewer parallels the west dike of the Santa Ana River southerly, and after picking up the clarified flow from New port Beach is discharged into the Pacific through a 3000-foot ocean outfall.

Unfortunately the river cut its west dike within a stone's throw of the screening plant, flowed over and destroyed the buildings and machinery (See pictures), and buried 3000 feet of the outfall south of the plant. Having broken the dike at the sewage plant, the flood waters spread over the wide low-lying area adjacent to the west river bank near the mouth and flooded the Imhoff tank and sprinkling filter plant of Huntington Beach. Breaking the east dike about a mile below the west dike fissure, water flowed over the low-lying area east of the river, flooded a main pumping station of the city of Newport Beach, isolated the new settling and sludge digestion tanks of that city and washed out some 500 feet of line leading from the plant to the Santa Ana Outfall.

Sewage from the Orange County Sewer District cities is now being heavily chlorinated and discharged into the Santa Ana River pending reconstruction of the treatment works and outfall. Effluent from the Newport Beach plant is being chlorinated and discharged into the river near its mouth, pending reconstruction of the connection to the Outfall. The ocean outfall line suffered no damage.

In general it may be stated that, while sewers and sewage disposal plants and appurtenant works in the storm stricken area suffered costly damages, repairs have been prompt and "service as usual" restored to citizens without incurring serious nuisance or menace to health—thanks to the availability of chlorine, which has come to be considered the emergency back-log of all time.

The author's thanks are extended to F. A. Batty, Maintenance Engineer, Los Angeles City; R. L. Patterson, City Engineer, Newport Beach; J. L. McBride, City Engineer, Santa Ana, and A. L. Frick of Wallace & Tiernan, for assistance in preparing this account.

With Regret

To Morris M. Cohn, past president of the New York State Sewage Works Association (1936), we owe an apology for having omitted his name in the caption under a photograph of "Past Presidents and Officials of N.Y. S.S.W.A." which appeared on page 110 of our February issue.

Neither were we very kind to Chas. C. Agar—retiring president of N.Y.S.S.W.A., when he was demoted (by caption) to become "Secretary Bedell's Newly Appointed Assistant" in our make-ready department. Mr. Agar's picture and Mr. Brigham's became switched in our February issue, the only excuse being—"Well they both were smoking man-sized pipes, and both hail from the New York State Department of Health."

We sincerely regret that we blundered so seriously in the pages of the N.Y.S.S.W.A. meeting report and ask forgiveness of Messrs. Cohn, Agar and Brigham.

Also we find there was a failure to run the usual acknowledgment line with Mr. Hetzer's paper in our March issue. His paper—"The Human Element of Public Relations"—was presented before the West Virginia Water Works Operators Conference, as reported in our December issue.

NEW JERSEY ASSOCIATION CLOSES BANNER MEETING WITH INNOVATION

ROUNDING out the most successful year in its history, America's oldest sewerage association—the New Jersey Sewage Works Association—held its 23rd Annual Meeting in Trenton, N. J., March 10th and 11th. The official registration of 230, although the highest on record, fails to reveal the real attendance which by conservative estimate reached between 260 and 280.

A unique scheme this year, to hold the attendance through to the end of the closing session, which was conceived and arranged by P. N. Daniels, long-time chairman of committee on arrangements and "inventor" of the Speechless Dinner, comprised the distribution of door prizes and an hour of high-class magic and ventriloquism put on at the close of technical session. Unique was the act of a top-notch performer who cajoled one of the members into serving as his voluminously perspiring dummy, much to the added merriment of his brother members. The scheme worked perfectly and the closing session was amongst the best attended of any during the meeting.

Top Notch Exhibits

In addition to the splendid weather, the excellent attendance and interest, another high-light was the exhibit hall which contained possibly the most varied, educational and overall attractive exhibits of 24 manufacturers and distributors which has ever been put on at a meeting of the Association. A few of the booths (the best lighted) were caught by the miniature camera for reproduction here. The list of all firms represented is appended for the guidance of members with whom the Treasurer and Business Manager, Paul Molitor, Jr., plead for support of such exhibitors and advertisers in the Annual Proceedings of N.J.S.W.A.

Business Meeting

The report of the Secretary and the Treasurer revealed the sound financial status of the Association, notwithstanding the fact that no fee for meeting registration is charged. To retiring President Edward Hyland was presented the official emblem of the Association as a token of appreciation of his service to it.

Chas. A. Capen, Chairman of the Legislative Committee, reported that the revised companion Operator Licensing Bills 278 and 288 were up for their 3rd reading preparatory to voting. Copies of each bill were distributed.

The Retiring President, Edward P. Hyland, Supt., Water Works and Sewerage, Moorestown, N. J.

The New President, Edward P. Molitor, Supt., Joint Sewage Works, Madison and Chatham, N. J.

Sec'y—"Wheel Horse"—Vice-Pres., John R. Downes, Supt. Plainfield Works, Bound Brook. (An Organizer and Veteran Secretary of the Assn.) Edward Schisler, Supt. of Sewerage, Haddon Heights (a Past President and "Wheel Horse"). Henry van der Vliet, Supt. of Sewerage, Maywood (the New 2nd Vice-President).

For the Committee on Sewerage Terminology, Chairman W. C. Mallileau presented some of the 53 new terms added to the revised and modernized list.

The following list of officers,* presented for the ensuing two years by Edward Schisler as Chairman of the Nominating Committee, were voted in unanimously:

President—Edward P. Molitor,* Springfield.
1st Vice-Pres.—Samuel R. Probasco,* Burlington.
2nd Vice-Pres.—Henry Van der Vlict,* Maywood.
Secretary—John R. Downes,* Bound Brook.
Treasurer—Paul Molitor, Jr.,* Morristown.

*All being superintendents of sewerage or of sewage treatment works.

Technical Sessions

(Edward P. Hyland, Presiding)

The Technical Sessions opened with a paper by B. DUNCAN MCCLAVE, Boro Engr. of Maywood, N. J. (boss of the new Vice-President) who discussed **"The Relation of Plant Operators to the General Public,"** in which he encouraged operators to "prepare in peace for the eventualities of war" by making friends of the general public by keeping them informed and by taking them into their confidence. He stressed the fact that even the best of operators should always be looking ahead with the thought of preparing for self-protection when needed. As an operators' motto he suggested "Be Prepared" not alone in operating matters but in combating those "adjustments" which licensing acts were intended to preclude, and in which public opinion was a most valuable deterrent. To establish recognition and encourage efficiency, Mr. McClave suggested that there be an award of "Certificates of Merit" from the State Department of Health to proficient operators.

"Some Factors in Chlorine Handling Not Too Well Understood by Sewage Works Operators"—by JAS. B. BATY, Technical Engr., Penna. Salt Mfg. Co., Philadelphia, Pa.

Mr. Baty's well presented illustrated talk pointed to the several most commonly encountered operating troubles and hazards found at chlorinating stations. He cited the work and the published report of the American Water Works Association's Committee on Safe Han-

Programmers

"Jim" Baty, Tech. Service Engr., Penna. Salt Co., Philadelphia, Pa. (a Product of the Lone Star State, Worked Formerly for Harry Croft). Jas. H. Allen, Engr. "Incodel," Philadelphia, Pa. *(Interstate Commission on the Delaware Basin). E. A. Bell, Boro Engr., Essex Falls, N. J. (Has a Combination Chemical Precipitation and Sand Filter Plant; the Results Speak for Themselves).*

dling of Chlorine and to the work of the Chlorine Institute's Committee on Safety and Transportation. Concerning operating troubles, reliquefaction of chlorine gas in the gas lines was perhaps the most common. Such could be overcome by preventing the chlorine container from becoming warmer than the gas line at any point along its way to the chlorinator. Another method was to employ pressure reducing valves on the line near the cylinders or ton containers. For gummy impurities reaching the chlorinators the chlorine had frequently been held to be "dirty" chlorine, whereas investigation uncovered entry of lubricating oil or of oil from pressure gages into the line through leaky diaphragms on such gages. The former tolerance of impurities in liquid chlorine, amounting to 0.2%, was completely out of date in 1938 because chlorine was being consistently produced with only 1/20th of this limit—i.e., 0.01% impurities and 99.99% pure chlorine.

Mr. Baty pointed out that 150 lb. chlorine cylinders at ordinary room temperature would yield continuously only 35 lbs. per 24 hours per cylinder connected; ton containers about 400 lbs. per 24 hours. Heating containers (to increase the discharge rate or boost pressure) was hazardous, aside from giving operating troubles. The fusible metal plugs in containers, put there for safety reasons, had a melting point of 157 degrees F. and therefore would stand but little heating. He showed pictures of the results of serious chlorine leaks caused by mistreatment of the cylinder valves with large wrenches which stripped the threads or resulted in cross-cut threads. He showed one valve which had been eaten away as the result of submerging the cylinder to absorb the leaking chlorine—the leak all the time increasing in size and gas coming to the surface.

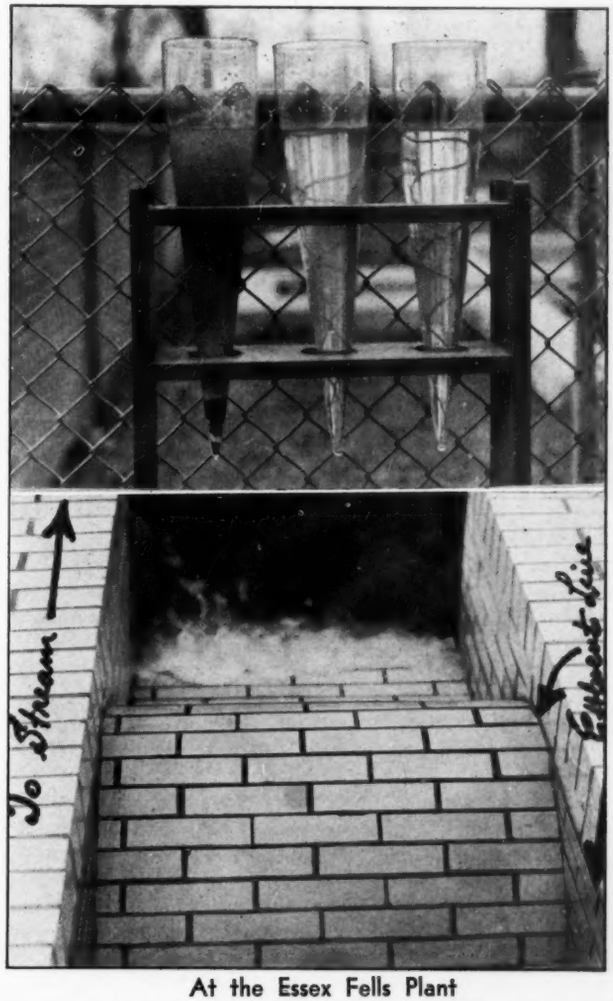
To loosen "frozen" valve stems Mr. Baty warned that the use of large wrenches was hazardous and recommended loosening the packing nut slightly and then tapping the head of the stem gently to jolt it loose. For making trouble and leak-proof connections of cylinders to the gas feed line, Mr. Baty endorsed the adaptor fitting and iron screw yoke, rather than the weaker union type connection. Its chief assets were simplicity, safety and time and valve thread saving.

What to do with leaking valves or fusible plugs, was the next important question. Mr. Baty pointed out that shipment of such leaking containers was illegal practice. So, there were two "DO NOT" rules at least: (1) Do not throw into water; (2) Do not attempt to ship back to the manufacturer. Leaks around the valve stem can frequently be stopped merely by short-wrench tightening of the packing nut. If necessary, the closed valve can actually be repacked while still under full pressure. Rule No. 1: use no lubricants on packing or valve stems. Leaking fusible plugs could be checked by use of the "C" clamp or by careful peening of the metal.

In the final analysis, should it be necessary to empty the cylinder the most satisfactory procedure had been to connect a garden hose to the valve with the outlet end *weighted* down at the bottom of a barrel of lime-slurry (1.25 lbs. of hydrated lime for every lb. of chlorine to be absorbed) and then bleeding the cylinder into it, surprisingly rapid rates being possible without chlorine loss. The hypochlorite produced can then be used or dumped into a sewer. Left to stand the lime slurry will actually be sucked into the chlorine cylinder in the end.

Mr. Baty then gave some rules in the way of first aid treatment of gassed men in which artificial respiration and the mixture of 93% oxygen and 7% carbon dioxide is employed in inhalators such as maintained by utility companies and fire departments. He referred to the standard "First Aid Recommendations of the Chlorine Institute," which were in the course of being printed on standard wall-placards for distribution to plants by member firms of the Institute.

"The Essex Fells Chemical Precipitation Treatment Plant"—by E. A. BELL, Boro Engr., Essex Fells, N. J.



At the Essex Fells Plant

(Upper) Typical Samples of Crude, Chemically Precipitated and Filtered Sewage. (Below) Weir in Plant Effluent Channel. Note Arrow Point at Flow Line, Otherwise Difficult to Detect in the Picture

With a Cockeyed Camera and Apologies of the Cameraman

(1) D. M. Dittmars and R. S. Shaw, Asst. Engrs., N. J. Dept. of Health; (2) Leslie West, Supt. Treatment Wks., Elizabeth, N. J., and Percy Boughton, Boro. Engr., Cedar Grove, N. J.; (3) Wm. Sylvester, Asst. Chief Engr., N. Y. Dept. Sanitation, and Elson T. Killam, Cons. Engr., New York City; (4) Raymond G. Case, Supt. of Sewerage, Merchantsville, N. J., and Thomas Whitehead, Supt. of Sewerage, Haddonfield, N. J.

Mr. Bell briefly described the chemical precipitation plant of Essex Fells, comprising the following units: Comminutors, Parschall Flume, Primary Settling, Flash Mixer, Aero-Flocculation, Secondary Settling. All sludges are digested in floating covered digesters. The chemical effluent passed to four sand filters (which served an old plant), the effluent of which is chlorinated before discharge to a stream drawn upon for public water supply. The plant (200,000 g.p.d. capacity), designed with aero-flocculation to employ the Guggenheim Process at a cost of $53,000, was placed in operation in November, 1936. The results of the treatment at various stages through the plant were clearly pictured in the lantern slides, two of which are here reproduced.

At such a small plant, said Mr. Bell, the use of chlorinated-copperas had not proved economically sound practice because of the cost of chlorine in 150 lb. cylinders and ferrous sulphate in L.C.L. shipments. Alum had been substituted and was more economical, even at higher dosages. The return of sludge to the aero-flocculating unit had been discontinued when found of doubtful value. The return of supernatant liquor had upset flocculation considerably. More recently, prechlorination had been found a practical corrective of the trouble at little added cost—making the total chemical cost only $7.89 per m.g. and power cost $50.00 per month for air compression and operation of all mechanical equipment. Mr. Bell explained that the scheme of pre-treatment at Essex Fells had not been reduced to a conclusive selection, but the Guggenheim Process had been discontinued for the time on grounds of cost and expediency. He felt that a still greater reduction in treatment costs (even considering the small size of the plant) was a further possibility.

In the control of chemical flocculation turbidity measurements with the standard Jackson Candle Turbidimeter (long used in water treatment) was employed—there being a defined relationship between turbidity of the flocced and settled sewage and the reductions of B.O.D. values therewith. For turbidity measure samples taken of crude, chemically treated, and final (sand filtered) effluent were taken twice during the day shift. At night, the sewage being mostly water, there was no need for preliminary chemical treatment. As an example (see photograph) Mr. Bell cited an alum dosage of 460 lbs. per m.g. as reducing the B.O.D. of settled sewage from 192 (turbidity 190 p.p.m.) to 42 B.O.D. (turbidity 33 p.p.m.) going to the sand units. Filtration further reduced the B.O.D. to 3. (turbidity 1 to 5 p.p.m.), requiring but 15 cents worth of chlorine per day for sterilization. Although designed for 200,000 gals./day, the overloads taken had been 50% without lowered efficiency of treatment or operating difficulties.

In view of his experiences, Mr. Bell concluded that chemical precipitation was practical for the small as well as the larger plants. The low initial cost, moderate chemical and power costs, and absence of odor or fly nuisances, were definitely in favor of this type of plant which had been selected by the engineers (Fuller and McClintock) for the Essex Fells residential district.

(1) Norman C. Wittwer, Sewerage Engr., Rahway Valley Commission, Rahway, N. J.; (2) R. S. Burr, Engr., American Brass Co., New York City; (3) Myron McLeod, "American City Magazine," New York City; (4) M. F. Wandling, Asst. Engr., N. J. Dept. of Health, Trenton; (5) C. H. Dickinson, Hooker Electro-Chemical Co., New York City; (6) C. S. Wileman, Engr., Link-Belt Co., Chicago; (7) Alan Wood, Builders Iron Foundry and "Proportioneers," Inc., Philadelphia, Pa.; (8) J. F. Boreiszo, Chemist, Rahway Valley Plant, Rahway, N. J.; (9) "Jimmie" (the) Angell (is he?), "Water Works and Sewerage," New York City.

"A Study of the Operation of the Essex Fells Plant," by ROBERT S. SHAW and D. M. DITTMARS, Asst. Engrs., New Jersey State Dept. of Health, Trenton, N. J.

The paper read by Mr. Shaw constituted a presentation of observations during a critical study of the operation of the Essex Fells plant, first during periods when the Guggenheim Process was employed and at other periods when other modifications of chemical precipitation were involved. The speaker confined himself to general statements, discussion and conclusions—stating that some 5,000 laboratory tests on 575 samples had been involved in the study and the records were available in the Department of Health files to any who wished to make a detailed study of such. With the Guggenheim Process (copperas at $20.00 per ton, chlorine in cylinders at 6 cents per lb. and hydrated lime at $20.00 per ton) the chemical costs had been $15.35 per m.g. during day treatment and $5.05 per m.g. during the night hours. With a return sludge loading of 17 per cent (1,000

p.p.m. solids in flocculators) dosages of 100 p.p.m. ferrous sulphate and 14 p.p.m. chlorine, for its oxidation, had reduced suspended solids by 74 per cent, B.O.D. by 84 per cent. With the introduction of pre-chlorination (no residual involved) there had been a further reduction of B.O.D.—only 27 p.p.m. remaining in chemical effluent as compared to a 42 p.p.m. residual without pre-chlorination. Later, the pre-chlorine dosage boosted to 7 p.p.m. more than offset the 20 per cent reduction made in copperas and lime applied.

Testing the effects of sludge return in the Guggenheim process (when pre-chlorination was being employed), the only observation of interest was that appreciably less lime was needed to maintain the optimum pH of 8.0 to 8.4 in the aero-flocculation stage after sludge return had been discontinued for a five day period. Result: a reduction of chemical cost amounting to $6.78 per m.g. plus the cost of recirculating and aerating returned sludge. Conclusion: the high lime dosage seemed of debatable worth and sludge return seemed to play no genuinely important role, while adding to operation costs.

A test of the value of primary settling ahead of chemical precipitation proved the method of some value in reducing chemicals but the question of economics of pre-settling was yet open to debate. A weakness discovered in aero-flocculation was the difficulty of air control and regulation in the Essex Fells design, so as to provide sufficient but avoid excess air creating detrimental effects in breaking up or stringing the floc.

In summary the following statements were made:

(1) The Guggenheim Process, as set by Guggenheim representatives, effected reduction of suspended solids 72 per cent; of B.O.D. 80 per cent; at chemical costs of $15.35 (day) to $5.05 (night) per m.g. treated.

(2) Sludge return proved of little or no value; the use of lime of questionable value.

(3) Preliminary sedimentation was of some value in chemical savings.

(4) Pre-chlorination (even without maintaining a residual) produced improved results without sludge return and enhanced economies. Under the circumstances 30 p.p.m. ferrous sulphate and 30 p.p.m. hydrated lime with 11 p.p.m. chlorine reduced B.O.D. by 93 per cent and suspended solids by 85 per cent when the B.O.D. of the crude sewage ran to 550 parts.

In respect to the study of loadings which the 4 old slow sand filters would handle successfully, it was learned that 2 units operating at 1.2 m.g.d./acre rates constantly failed to produce any appreciable nitrification. Three units 0.7 m.g.d./acre have proved ample to handle the average flow of 0.2 m.g.d. of the chemical effluent to date.

(What has not been studied at Essex Fells is the value of a high rate mechanical (straining) filter to remove the suspended solids loadings from the fine grained biological units. Both in economy of filter maintenance and chemical costs there is some reason to believe that further studies may reveal much of value at Essex Fells, as pointed out by Mr. Bell.—Ed.)

"Incodel"—Objectives and Problems

"The Objective of the Interstate Commission on the Delaware River Basin," by Senator R. C. HENDRICKSON, N. J., Member of "INCODEL," Trenton.

Mr. Hendrick reviewed the reasons behind the establishment of the Interstate Commission on the Delaware River Basin, consisting of 4 members from each of the state of New Jersey, Pennsylvania, New York and Delaware, and chiefly concerned with the uses of the waters of the Delaware Basin for water supply and disposal of wastes, and financed by the Commission on

Wellington Donaldson, Engr. of Treatment, New York City. (The "Duke" Is Now an Admiral; Has Three New Sludge Steamers in His Fleet.) Harry W. Gehm and Dr. H. Heukelekian, Div. of Water and Sewage Research, N. J. Exptl. Sta., New Brunswick.

Interstate Corporation of New Jersey and New York ($7,500 per year each); Pennsylvania ($12,500) and Delaware ($2,500). As to the 12 months of progress, Mr. Hendrickson pointed to the open-forums held on the matter of what agencies should handle stream control and resultant resolutions forwarded to Washington opposing Federal control and proposing regional control. Realizing Philadelphia to be the greatest offender in polluting the Delaware, and far behind in her promises to state authorities, actions had been started and her reply was now being studied by Pennsylvania Sanitary Water Board. Camden, across the river was ready and willing to abate pollution when Philadelphia came up to its promises. Other movements were also touched on in the Commission's goal of "equitable treatment of one to another and fair dealings amongst those in the Delaware Basin."

"Engineering Problems in the Delaware Basin," by JAMES H. ALLEN, Engr., "INCODEL," Phila.

Mr. Allen explained that "INCODEL" was established on the score that cooperation was essential, and that the new agency might well see the broader interests than individual state agencies. The chief purpose now was to supplement and harmonize the working of existing Water Resources Boards of the four states. The main stem of the Delaware and its tributaries had been classified insofar as pollution tolerances were concerned. From Easton to Trenton, and for all tributaries above Trenton, the highest degree of wastes treatment had been set. Below Trenton primary treatment of domestic sewage and trade wastes treatment to produce equivalent of domestic sewage was to be required. The really bad spot was the Philadelphia-Camden area and below Philadelphia. Providing primary treatment to but 1/7th of its sewage Philadelphia was $26,000,000 behind in its program promised the State Department of Health 30 years ago when ordered to curtail pollution. Since the legalizing of sewer rental charges in Pennsylvania, Philadelphia no longer could rely on the time worn excuse of poverty, and the State now had ample power to clamp down. All loop-holes are being plugged and "INCODEL" expects to push the Philadelphia-Chester area problem and Camden was expected to fall in. (If Mr. Allen and his commission can get something accomplished in the Philadelphia area—more power to "INCODEL," say we. It must be a powerful city, founded on "Brotherly Love," that can defy orders of its State Health Department for 30 years, while a sister city below drinks its sewage.—Ed.)

"Operation of the Morristown Activated Sludge Plant," by PAUL MOLITOR, JR., Supt. of Sewage Works, Morristown, N. J.

Mr. Molitor briefly described the Morristown plant, designed for 20,000 persons (2 m.g.d.) by Weston

Gavett, Cons. Engr., which comprises primary settling (1.5 hrs.); diffused air aeration (4.5 hrs.); final clarification in central feed square tanks (2 hrs.); separate sludge digestion (2.5 cu. ft./capita) and power generation from the gas; chlorination.

Originally equipped with drilled copper tubing, for air diffusion, "Aloxite" tubes had been since installed and a form of tapered aeration was being practiced. One digester is equipped for high temperature digestion. An 8 cylinder 150 H.P. Buffalo engine operates on digester gas to drive the compressors. A unique feature is the partial initial air compression, secured by effluent drop at the plant. From sand-beds all dried sludge is used on school grounds.

Citing some experiences, Mr. Molitor pointed out that sludge reaeration had not produced benefits at Morristown, and until the first compressors (vertical cylinder) were replaced by Connersville blowers operating troubles were many, denoting aeration deficiencies. Even now, every Spring and Fall for 2 to 4 weeks there occur periods of "unrest" in the plant accompanied by sludge "bulking." The floc becomes fine, fluffy and "uneasy" and a slimy scum indicates filamentous growths, which have been remedied by mild chlorination of returned sludge. Another trouble has been red worm (larvae) breeding. Correctives included a temporary super-dosage with bleaching powder and copper sulphate (both at once in one instance) and then starting over again. To keep apace with "uneasy" sludge, speeding up the sludge return rate has helped maintain a lower blanket and gets the sludge back to air with the least delay. Trials of sludge reaeration proved of no help by comparison.

Typical results—B.O.D.'s crude = 284; settled = 190; final = 24; avg. flow = 1.3 m.g.d.; avg. operating costs = $35.12 per m.g. Income from sewer rental ($3,000) had been charged those outside of corporate limits, reducing the treatment to a net of $29.31 per m.g. to the city proper.

Amongst the Booths of the Exhibitors

(1) Pennsylvania Salt Co.; (2) Link Belt Co.; (3) Pacific Flush Tank Co.; (4) Chicago Pump Co.'s Unique Demonstration of Their "Swing-Diffuser" and Tapered-Aeration; (5) Trohn's Supplies, Inc., Featuring "Tapax" Cushioning Tape for Banging Manhole-Lids.

Research and Experimentation

In reviewing experimental work, completed or under way, at the N. J. Water and Sewage Experimental Station, Dr. Willem Rudolfs had some enlightening comments for his intent listeners on matters pertaining to the most important studies—(1) underlying principles of the activated sludge process; (2) chemical coagulation of sewages and wastes; (3) pathogenic organisms in sewage and surface waters; (4) effects of ground garbage on sewage treatment; (5) treatment of industrial wastes; (6) effects of trade wastes on sludge digestion.

Highlights from the Activated Sludge Studies:

(1) Ample oxygen (air) is essential in the first (clarifying) stages, the use of nitrogen gas being a failure. Large quantities of carbon dioxide are there formed, while starches disappear rapidly through diastatic action, and with little or no sugar or acid production;
(2) Nitrogenous matters go more slowly (5 hrs.), but hydrolysis is speeded up with a larger supply of activated sludge;
(3) The studies have thrown some doubt on the base-exchange theory in accounting for ammonia absorption by the sludge.

Highlights from Coagulation Studies:

(1) Ferric salts have the power of "fixing" some organic matter, rendering it non-available as bacterial food, and thus iron precipitation accounts for oxygen demand reductions beyond flocculation alone.
(2) In comparing coagulants it seems that which is to prove most effective and economical must be determined for the conditions at hand and is not subject to prediction.
(3) Additions of powdered inert substances proved of dubious value in reducing coagulant or in aiding clarification.
(4) Acidification to control pH values proves of material aid in specific cases.
(5) As a mixing agent in flocculation, air seemed overall preferable to non-oxidizing gases tried.

Concerning garbage in sewage and effects on treatment, the following tentative conclusions have been reached: (1) The garbage of a community will double the suspended solids content of its sewage; (2) Grit will be more putrescible; (3) The oxygen demand of the settled sewage increases materially and pre-settling has little value in consequence; (4) The mixture can be coagulated at additional expense for coagulants, more especially iron salts; (5) The effluent is subject to activated sludge treatment but exerts a stronger initial rate of oxygen demand; (6) Garbage-sewage sludge (digested or undigested) dewaters readily on vacuum filters with coagulants; (7) The chlorine demand of the sewage increases in proportion to garbage liquor increases; (8) The last is only moderate, however, when the effluent is from chemically precipitated mixtures.

Highlights on industrial waste treatment studies: (1) The addition of 1 per cent acid pickling liquor from a steel mill reduced b. Coli in sewage by 85 per cent; 5 per cent by 98 per cent; 10 per cent by practically 100 per cent; (2) Some trade wastes in sewage retarded sludge digestion, others improved it when not in excessive quantities and increased gas production (details not given); (3) Thermophyllic (high temperature) digestion was less affected than low or moderate temperature digestion, although odor and drainability of high temperature sludge was more adversely affected, as was total gas production.

Miscellaneous studies dealt with laboratory methods (bacterial, chemical, and physical) the outcome being the development of an improved method of estimating b. Coli index of polluted waters; another the isolation

Speakers

Weston Gavett, Cons. Engr., New York City; G. M. Eisenburg and F. N. Moerk, Cons. Engrs. (Address Unknown, Due to Failure to Register).

and cultivating of pure cultures capable of producing clotting and clarification of sewage and simulating activated sludge within 18 to 24 hours of aeration, following seeding of the sewage with one or two of the organisms.

"Sludge Digestion at Moorestown," by F. N. MOERK and G. M. EISENBERG, Consulting Engineers (address unavailable due to failure to register).

Reporting a study of sludge digestion at the Moorestown plant, where much of the sludge was 7 to 8 years old, the solids content was found to be 15 to 21 per cent and solids reduction by calculation was 66 per cent. From this point the authors presented a preliminary report of findings in a study involving aerobic—digestion (wet burning) of sewage sludge solids as distinct from the usual anaerobic digestion and combustible gas production. Seemingly a 21 day period of aerobic digestion air blowing or splash recirculation was ample for reduction of 80 per cent volatile in sludge to 41 per cent and increasing mineral ash content by 163 per cent. The explanation offered was that of constant bacterial density in aerated sludge as compared to rapid increases in anaerobic digestion. Particularly was there a marked increase in fungi and liquefying organisms and cellulose digestors in the aero-digestion, it being concluded fungi multiplication to be the important factor in rapid disappearance of the putrefactive carbonaceous materials. The results at Moorestown have placed a new light on speeding up sludge digestion.

This paper, due to the limited period of study and data questionably representative of actual conditions, brought forth considerable questioning of the authors, and doubts in the minds of many that the limited results justified formulating conclusions or publication of any claims for the method. John R. Downes—veteran operator—pointed out some of the fallacies of the conclusions. Others questioned the practical significance

Barber Shop to Breakfast Table!

(Left) Picture of a City Mgr. Attending a Sewage Works Meeting—City Mgr. Paul Morton, Formerly of Lexington, Ky., Now of Trenton. (Right) "Prof." Lewis Carpenter (N. Y. Univ.) Learns From E. Sherman Chase (Metcalf and Eddy), "How to Digest Mixtures of Garbage and Sewage Sludge."

of such studies in the face of the economies of gas utilization in anaerobic digestion. Dr. Rudolfs, also doubted that the conclusions reached were correct. He had previously studied and reported on aerobic digestion, pointing out the more rapid rate for aerobic digestion, but a 21 day period without heat seemed a bit optimistic. The failure to account for the material leaving in the supernatant liquor might explain much and the Doctor questioned the economy of air agitation. Possibly extended studies would prove the first results less optimistic than they appeared on this presentation, which was seemingly premature. Weston Gavett spoke in complimentary terms of the endeavors of investigators Moerk and Eisenburg, regardless of the fact that the ground work of their studies might not be as strong as desired. He thought the possibilities deserved extension of the studies, as promised by the authors.

Sludge Incineration

"The Present Status of Sewage Sludge Incineration," by ELSON A. KILLAM, Cons. Engr., New York City.

Mr. Killam, dealing with perhaps the oldest and certainly the most persistently important factor in sewage treatment, the effective disposal of sludge, reviewed progress and developments in the modern practice of incineration as the one "complete" method of disposal of sludges—alone, or in combination with garbage and refuse.

In incineration practice Mr. Killam named the two

Joe Roberts, Distr. Mgr., Chain Belt Co., New York City; Philip Trohn, Pres. Trohn's Supplies, Inc., Mamaroneck, N. Y. (When He Steps on a Man-Hole Lid It Bangs—"Tapax" or No "Tapax.") Eric Hartmann, Vice-Pres., Inertol Co., New York City.

distinctive types of incinerators—(1) the multiple hearth furnace, providing progressive drying and incineration through a single unit; (2) the flash drying type, which involves drying in one stage followed by incinerator firing with the resulting powdered sludge, or optimal use of the latter as fertilizer. Especially was the combination of garbage and rubbish burning with sludge cake claiming attention on the basis of expediency and economy of the construction and operation of combination waste treatment plants on a common site and, thereby, bringing sludge destruction into the reach of smaller plants than has heretofore been considered practicable.

Modern sludge incineration got under way in the notable development of 1934 at Dearborn, Mich., at America's first modern chemical precipitation plant, and established the practicability of the burning of a difficult sludge (46.8 per cent volatile matter), with reasonable auxiliary fuel requirements, in the new type of modified rabble arm multi-hearth furnace transplanted from the mining to the sewage field. Mr. Killam then enumerated the features of the multi-hearth furnace and its

operation—which has since been installed (or under construction) at upwards of 20 plants in the United States—the smallest being a unit 9 ft. 3 in. diameter and the largest for Detroit to have a diameter of 22 ft. 3 in. and 12 hearths. Of these plants various quality sludges and screenings are to be incinerated, five to destroy ground garbage with the sludge cake.

Another type of sludge incinerator, put under development at the Chicago Sanitary District plant in 1933 involves a two stage operation in continuous sequence. The first stage is flash drying to produce a pulverant product of 10 per cent moisture, suitable for burning as powdered fuel under boilers or taking off for sale as fertilizer at will. Mr. Killam briefly described the features of design and operation of the flash drying incinerator, the largest installation being the Chicago (Calumet) Plant units with capacity for handling 6,000 pounds of net dry solids per hour, in the form of sludge cake of 80 to 85 per cent moisture, and involving 24,000 lbs. of moisture evaporation per hour. The installation at Neenah-Menasha, Wis., has a capacity of 3,500 lbs. of evaporation and 1,500 lbs. of dry solids per hour in the form of filter cake from chemical precipitated or primary digested sludges. Interestingly, the clay content from paper mill wastes dropped the volatile solids of the cake to 35 per cent at times, making incineration control a more tricky operation. At Buffalo, N. Y., similar equipment is going in, to destroy partially digested or crude primary sludges, providing a three unit capacity of 15,000 lbs. evaporation per hour. Under construction at the gigantic Southwest Plant of Chicago are the 8 largest flash drying units and 4 furnaces yet designed, providing a combined evaporation capacity of 80 tons of water per hour. In this case steam generation and electric power production from the burned sludge, plus auxiliary fuel, is involved. The smallest installation is that underway at Tenafly, N. J. (under Mr. Killam's direction) where garbage and rubbish is to be destroyed with undigested sludge cake and screenings, and involves an evaporation capacity of 700 lbs. of moisture per hour. An open hearth incinerator, of conventional design, is to be employed for the actual burning.

In summary, Mr. Killam said that it now appeared that a real goal in nuisanceless and sanitary complete sludge disposal was now at hand with vacuum filter dewatering and filter cake incineration, the selection of process and equipment necessarily being based on a study and consideration of local conditions, with its variables and requirements, if one was to reach the most economical solution. Such variables as sludge cake quality (volatile ash and water content, and B.T.U. values per pound of volatile on the dry basis) had to be considered and weighed in reaching the most economical and practical solution. This, however, should not jeopardize the present position and future of incineration equipment, properly selected and designed for service under specific conditions. Discussion of comparative economics and costs being somewhat premature until more operating experience is gained, Mr. Killam preferred to leave such for a future time.

"The Use of State Waters for Recreational Purposes," by R. VAN NEST BLACK, Director, N. J. Planning Board, Trenton, N. J.

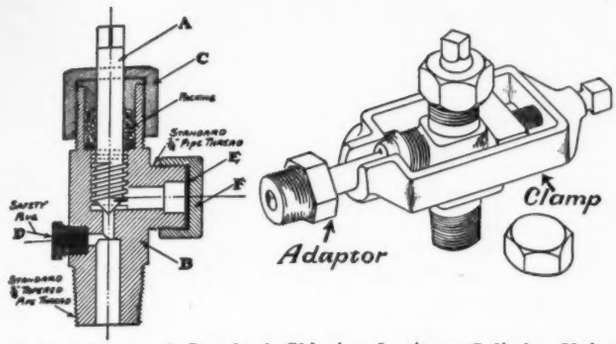
In speaking of conditions of the waters of New Jersey, Mr. Black noted progress in stream reclamation as evidenced by such projects as that of the Raritan Valley clean-up, and those of the Elizabeth and Rahway Valleys. He stated the need for classification of N. J. streams, as now being undertaken by his Board. He felt that fishing on the larger water supply reservoirs was a reasonably safe recreational privilege. He noted the need for a program of industrial waste treatment, as the next forward step in stream improvement, to relieve existing situations and make water supply sources less alluring to the recreation bound public.

(1) *Arthur J. Maahs, Engr. Johns-Manville Corp., New York City;* (2) *H. K. Gatley, Fuller and McClintock, Engrs., New York City;* (3) *"Lou" Brennesholtz, The Carborundum Co., New York City;* (4) *Harry J. Krum, Supt. Filtration and Sewage Works, Allentown, Pa.;* (5) *Frank K. Burr, Merrimac Chemical Co., Boston;* (6) *John G. Albertson, Thos. F. Bowe, Engrs., New York City;* (7) *Ellis K. Phelps, Pardee Engineering Co., Long Island City, N. Y.;* (8) *Robt. A. Hartom, City Engr., Ridgewood, N. J.;* (9) *Fred Stuart, President Activated Alum Corp., Baltimore, Md.*

"The Control of Water Supply Sources by the N. J. Policy Commission," by H. T. CRITCHLOW, Chief, Engr., State Water Policy Commission, Trenton, N. J.

In the absence of the author, his splendidly prepared paper was read and interpreted in equally splendid fashion by John M. Brooks, Assistant Chief Engr., of the Commission. Much of the paper hinged on quoted passages taken from important court decisions which are difficult to present in a digest of this nature. To any desiring to take water supply from N. J. surface water, and to municipalities tapping ground waters, permission must be secured from the Water Policy Commission as well as the State Department of Health. Strangely, industrial and private corporations (water companies excepted) are legally without reach of the Commission. (We understand that something of the same situation has long existed in England, steps now being taken to place all water takers on the same plane in respect to control.—Ed.) Use of lakes and upland streams for recreational purposes or concessions constitute a problem, and already 710 of the 800 lakes and ponds of New Jersey are used for recreational purposes. No permits had been granted to date for any usage which might endanger public water supplies, but there was constantly the question of private interests demanding proof of danger from reasonable usage of such water bodies.

Concerning classification of streams Mr. Critchlow referred to complications due to the growing clamor for recreational facilities and reasonable and equitable usage of public water bodies. Mr. Brooks explained that the



(Right) Improved Standard Chlorine Institute Cylinder Valve. (Left) Clamp and Adaptor, Recommended for Simplicity and Safety.

authority of the State Department of Health (according to existing law) to prevent pollution required that it first establish the fact that pollution and hazard to health exists. Fortunately, for the health authority, the Water Policy Commission had the powers to step in ahead to prevent pollution, rather than order such stopped after menace could be proven.

E. S. CHASE, Metcalf and Eddy, Engrs., came down from Boston to applaud New Jersey's Court of Appeals and the Water Policy Commission in their belief that there were ample areas for recreation outside of public supply areas.

Fire and Explosion Hazards

"Fire and Explosion Hazards at Sewage Works," by ROBERT M. CADMAN, Supt., Engineering Dept., Schedule Rating Office of New Jersey, Newark, N. J.

Seemingly no paper on the program was more intently listened to as was that by Mr. Cadman. Certainly no other received the same degree of discussion, which ended in a floor recommendation that a Joint Committee on Sewage Works Hazards be set up to comprise representatives of the Association with those of the Rating Office and the N. J. League of Municipalities. We understand that such a committee will be established and be asked to render a report, with safety recommendations, during the 1939 meeting.

Mr. Cadman's paper listed and briefly reviewed the most recent fires and gas explosions at sewage treatment works. Strangely, little was said about sewer explosions or known deaths due to asphyxiation, or hydrogen sulphide poisoning of sewage works employees. The fact that toxicity of hydrogen sulphide ranked with hydrogen cyanide gas was mentioned, however. The ratios of gases or gasoline vapor to air volume to produce flame and explosion were cited in a table—hydrogen sulphide being not alone deadly but more explosive than methane or sludge gas—the latter being between 5 and 16 per cent and gasoline fumes 1.3 to 6 per cent. In each case above at the higher figures burning resulted but explosion would probably follow when air could get into the burning system.

Mr. Cadman closed with a compilation of 17 safety recommendations from which the following have been taken.

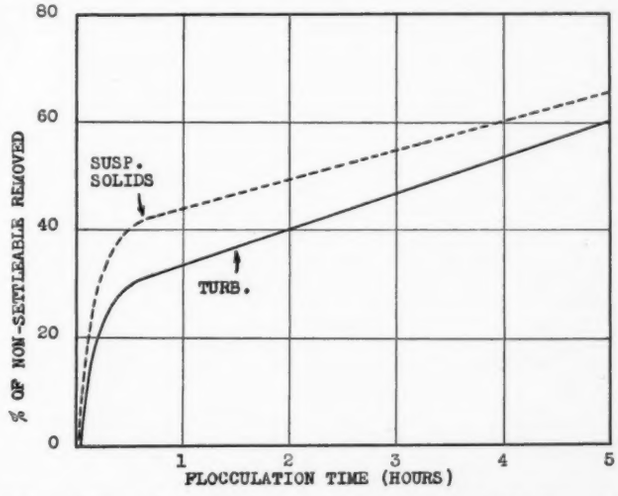
(1) More attention is needed to effective sewer ventilation;

(2) More rigid, and rigidly enforced, ordinances are needed to preclude discharge of flammable liquids or industrial wastes into sewers; (4) Erect no buildings over digestion tanks or sumps where sewer or sludge gas can accumulate in them; (5) Sludge digester mechanisms should be effectively grounded to preclude spark jump or static discharges; (6) Gas burning equipment should be located in a room or enclosure cut off from the rest of the building by standard fire walls and with entrance to the furnace room from the outside only, and provided with adequate ventilating system to preclude explosion; (7) Such enclosures should be provided with liberal thin (not reinforced) glass sash to burst in case of explosion and save the roof and walls; (8) Concrete tank roofs forming building floors should be treated to effectively seal the pores against gas seepage; (9) All gas piping and appliances should be installed in keeping with Recommended Good Practices of the National Board of Underwriters covering installations in connection with city gas use; (10) The use of approved flame traps should be liberal; (11) Digestion tanks should be purged and ventilated thoroughly before entry; (12) Containers of chlorine not in actual use should be stored in a fireproof type structure, preferably detached and used for no other purpose, and kept locked.

LESLIE E. WEST, Supt. Treatment Works, Elizabeth, N. J., commented that hazards had increased materially with mechanization of plants and gas utilization. He cited a case of a serious explosion at a junction-manhole on the Elizabeth Trunk Sewer at Union, N. J., having been caused by seepage of gasoline vapors into the prechlorination building over the manhole. The electric heater having been too costly to keep running, a pot-stove installed had served as the source of ignition. The accident had resulted in a rigid ordinance against gasoline, benzine and oil discharge into the sewer. In addition, an effective ventilation scheme had been designed to release gases and take in air.

MR. KLEGERMAN, Engr. with Alexander Potter, spoke at some length on the need for greater respect for the dangerous hydrogen sulphide in sewers and treatment works, which justified tests for the production and taking corrective measures to prevent poisoning, damage to electrical equipment and the like, and explosion. Watching for compressor temperatures, realizing that at 480 deg. F. many lubricating oil mists carried along with the hot air would actually ignite and explode, was another precaution suggested.

NORMAN C. WITTWER, Supt., Rahway Valley Sewerage System, said that it was to be noted that all explosions of digesters had occurred in connection with rigid (fixed) roof tanks. To his mind this pointed to the preference for floating cover digesters and amply large gas holders. For purging digesters when emptying he



Effect of Flocculation Periods on Non-Settleable Solids Removals at the End of One Hour Settling. (The Curves Reveal the Close Parallel Between Removals of Non-Settleables and Turbidity as Simply and Rapidly Determined by "Standard Methods" Procedure.)

suggested carbon dioxide or nitrogen gas. He thought essential that plants be designed to preclude explosion hazards with reasonable care in operation.

L. H. ENSLOW, held that design was wholly responsible for the Bristol, R. I., explosion where proper precautions to lead the water seal blow pipe outside of the building had not been taken. However, the trouble was likely from the chokage of a waste gas line due to the severely cold weather and the frost choking of the pipe, due to the cumulative freezing out of the moisture from the water saturated digester gas. The consequent stoppage of the waste gas flow caused the water seal to be blown. In theory, the seal in the digester dome should have blown first, but theory did not prevent the explosion. Proper grading and drainage of gas lines (preferably over-size in diameter), and some degree of insulation to prevent internal frost build up, seemed worthy of real consideration. Answering a question, Mr. Enslow explained that the frost ring formed on the inside walls of exposed gas lines just as ice formed in large water lines or hard scale in boiler tubes. With continued freezing temperatures the frost was laid down ring on ring until eventually the complete blockage resulted. The smaller the clear opening through the pipe the more rapidly did the hole grow smaller as long as the gas flow with its moisture content remain constant.

Mechanical Flocculation

"A Study of Mechanical Flocculation," by HARRY W. GEHM, Div. of Water and Sewage Research, N. J. Experimental Station, New Brunswick, N. J.

Mr. Gehm, reporting on laboratory studies of mechanical slow-motion mixing, as a flocculating process unaided by chemical coagulants, revealed that the most practical index of purification attained had been the measure of turbidity reduction in the flocculated settled sewage. In fact, reduction of non-settleable suspended solids and B.O.D. values, when plotted with turbidity reductions, produced parallel trend curves all the way through. In the accompanying representative graph the complete story of relationship of period of flocculation, clarification, and purification is essentially told. In general the economical limits to flocculation period appeared to be 25 to 35 minutes, followed by a settling period of 1 hour. With increasing strength of sewage removals of non-settleables increased—the improvement being negligible on weak sewages (10 p.p.m.) and running up to 40 p.p.m. B.O.D. reductions (20 per cent) on the stronger sewages as compared with removals obtained by settling alone. Briefly stated 30 minute mechanical flocculation plus 1 hour settling proved about equivalent to several hours of plain settling, and proved most worth while on the stronger sewages tested. (Interesting are the New Jersey results, which compares with 15 per cent added B.O.D. reductions reported some time back on the domestic sewage of San Francisco and variably higher reductions on the stronger packing-house waste impregnated sewage of Cedar Rapids, Ia. —Ed.)

Exhibitors

The following 24 firms comprised those which had exhibits constituting the most interesting and educational equipment and materials display ever held by the New Jersey Sewage Works Association, justifying the ample time allowed between sessions for their inspection.

American Brass Co., Waterbury, Conn.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., Chicago, Ill.
Ralph B. Carter Co., New York
The Dorr Co., New York
Eimer & Amend, New York
Fairbanks, Morse & Co., New York
Flexible Sewer-Rod Co., Irvington, N. J.
W. & L. E. Gurley, New York
Hardinge Co., New York
Homelite Corp., Rochester, N. Y.
Inertol Co., New York
Johns-Manville Co., New York
Kingston Trap Rock Co., Kingston, N. J.
Link Belt Co., Philadelphia
Lord and Burnham Co., Irvington, N. Y.
N. J. Lab. Supply Co., Newark, N. J.
Pacific Flush-Tank Co., Chicago
Penna. Salt Mfg Co., Philadelphia
Proportioneers, Inc., Providence, R. I.
Arthur H. Thomas Co., Philadelphia
Trohn's Supplies, Inc., Mamaroneck, N. Y.
Wailes, Dove-Hermiston, New York
Wallace & Tiernan Co., Newark, N. J.

▼

THE "ROYAL FAMILY"— PAUL I, II & III

In the sewage works field New Jersey boasts a "Royal Family"—the Molitors. In this snapshot of three generations is Paul, Sr., the beaming granddad of Paul III and proud father of Paul, Jr. (right), Superintendent of Sewerage at historic, ploutocratic Morristown, N. J.; who is Treasurer and Business Manager of America's oldest sewage works association.

Proud also, is Paul, Sr. of another son, Edward P., who succeeded his father as Superintendent of the Madison-Chatham Sewerage Works, and who has just been elected President of the New Jersey Association. Paul, Sr., affectionately referred to as Jersey's "Dean of Operators" and as the "Maestro of Sewage Treatment," was present at the birth of the N. J. Association, served as its first secretary and thereafter as its president.

In those days the chief problem confronting operators of new plants was that of "Imhoff tanks that worked up-side-down—the cause and remedy." On this topic there were many hours of debate; Paul I had such a plant—the first in America; Paul, Jr., and Ed. watched it foam and wondered, while Daddy sweated over his troubles, wondered how Imhoff made 'em work and why in "H—" George Fuller (the late and eminent designer) ever brought the idea back with him from Germany, anyhow. In the meantime, Paul I got a modern plant for Chatham-Madison and his two apprentice sons grew up to become leaders amongst operators and "Supers" in their own name. And, in consequence, we dub the Molitors—"The Royal Family."

The Molitors: Paul I, II and III.

SEWER MAINTENANCE

By JOHN H. BROOKS, JR.*

Superintendent, Sewage Dept., Worcester, Mass.

A SEWER system, in providing services for the handling and disposing of the domestic and industrial waters of any community, is fully as essential as the many other requirements of our modern civilization.

The Author

Sanitation in most communities has progressively developed. Therefore, most sewerage systems today represent the results of year by year improvements and additions made to the original sewers built early in the history of the system. It follows, therefore, that many such systems comprise sewers built many years ago. Frequently their design and condition are inadequate to handle the present day requirements.

The early sewers of most communities were installed to provide not only for the handling of polluted water but also for the disposition of surface water. With the demand for the abatement of pollution of the natural waterway outlets, where the pumping of sewage was necessary, and with the advent of sewage treatment, this excess volume of storm waters made necessary the installation of separate sewers. Many cities, therefore, have all these types of sewers, combined, sanitary and surface, with appurtenances comparable to their respective types. Each of these classes of sewers presents a particular problem of construction and of maintenance.

**The author of this article has the distinction of being president of the New England Sewage Works Association. He enjoys an enviable service record as superintendent and engineer of the Worcester Sewer Department under many administrations.—Ed.*

The maintenance of a modern public sewer system, as its term implies, pertains to the keeping in repair and in operating condition all of the fixed properties of such a system. The treatment and final disposal of sewage is not considered a function of sewer maintenance and will not be discussed in this article.

Sewers, upon their completion, are immediately put into use. Their position beneath the surface of the ground removes them from the eye of the public. Until trouble develops their existence is forgotten by the layman. Maintenance, however, must be attended to from the date of their completion.

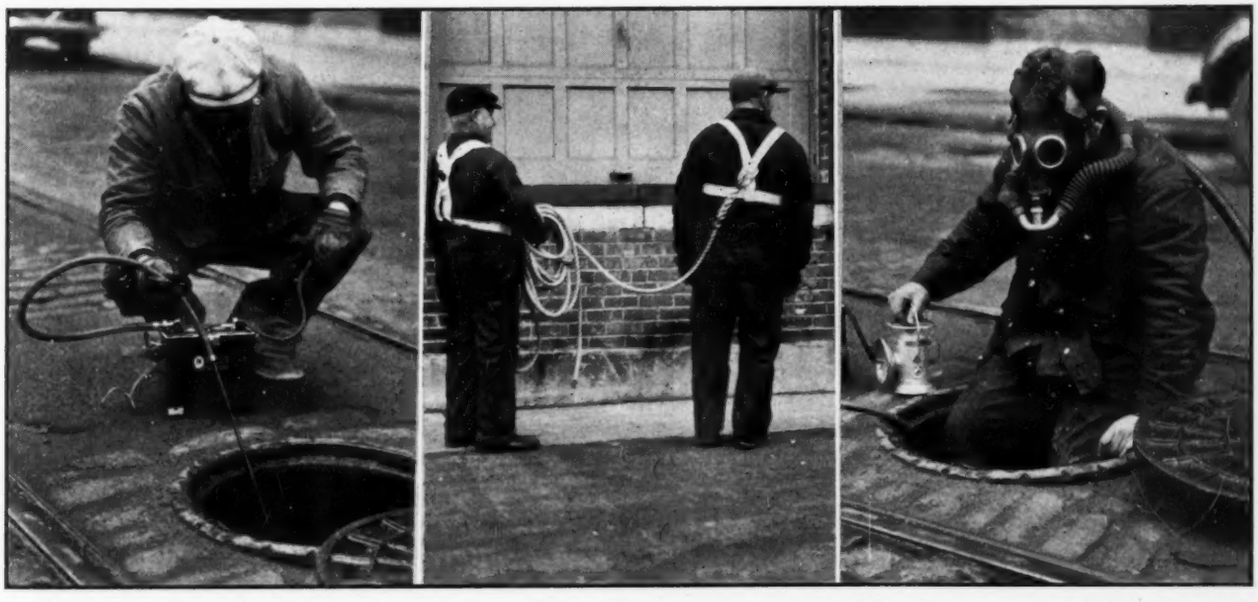
Sewer Maintenance Practices

The author's experience has been gained in the construction and maintenance of the public sewer system of Worcester, Mass. Practices and methods employed in Worcester are presented, not necessarily as ideal or perfect but as a typical illustration of what such procedures can be.

The Worcester Sewer System consists of nearly 400 miles of sewers, of which 70.1 miles are of the combined type. Over 10,000 manholes and more than 7,000 catch basins are a part of its system. While this sewer system is established and built on a gravity flow principle there are four districts of considerable area from which sewage has to be pumped.

Few inland cities are endowed with such good natural drainage facilities as Worcester, and the natural topography early dictated the establishment of a gravity layout for sewerage. The Sewage Treatment Plant quite naturally is located at the city boundary and discharges to the smallish Blackstone River where it leaves the city.

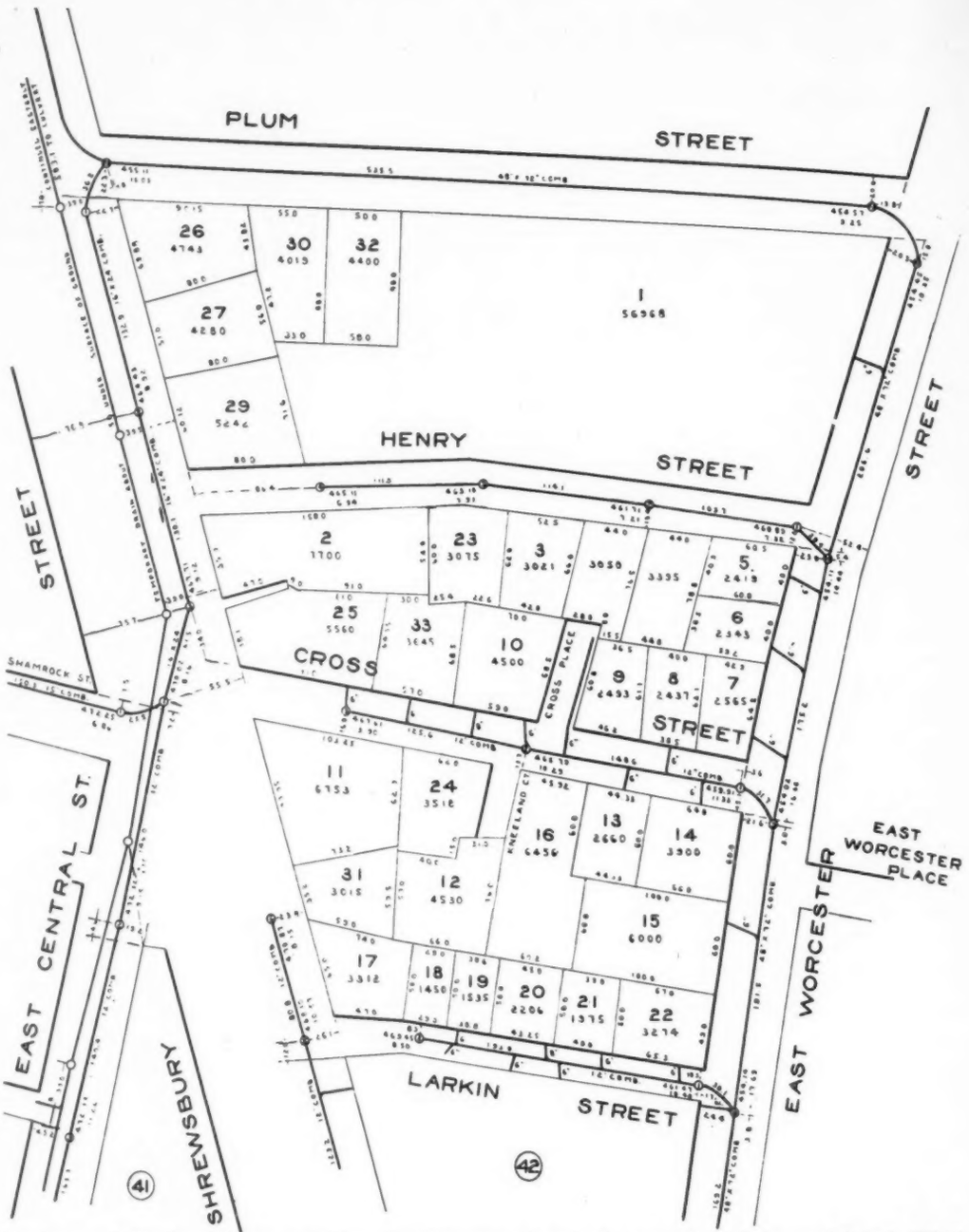
In the early establishment of its sewerage this stream with its tributaries was utilized for the disposal of the



"Why Take Chances?"—Good Men Are Too Scarce. (Left) This Foreman Tests a Manhole for Gas. (Right) Didn't Look Too Good, So He Sends This Man Down With Fresh Air Hose, Mask and Safety Lantern, "Feet-First" So He Wouldn't Be Coming Out That Way. (Center) A Worthwhile Precaution in Any Event Is to Insist That the Man Go Down with a Life-Belt on and That Two Good Men Are Available to Pull Him Out in Case He Stops Whistling.

wastes of the community. Natural pollution took place which early required measures for its abatement. Worcester's record in sewerage and sewage treatment has consistently kept abreast of the developments in the sanitary field.

The early system Worcester's sewers date from 1855 and were of the combined type of which some seventy miles are still in use. The main water way (Mill Brook) flowing through the city set up throughout this district a natural barrier for a main carrier. Two interceptors are, therefore, provided one on each side of this main waterway, each of which discharge into a main outfall sewer which conveys the sanitary flow of the city to the Sewage Treatment Plant. Throughout the district still served by combined sewers, at times of storms there constantly arises peak flows. By means of storm flow regulators this excess volume is diverted into Mill Brook.



Specimen of Sectional Maps Covering the Worcester Sewer System (Scale 1 In. = 400 Ft.) Which Were Started in 1936.

The responsibility for the design and layout of Worcester's sewers is placed with its Engineering Department. Complete plans and data have been built up and recorded. These records are consistently reliable except for such data as has become obsolete or valueless because of physical changes in street surfaces, lot boundaries and other structures which originally were used as witness marks. Except for some of the early sewers of Worcester (built by contractors), all public sewers have been constructed by city forces. The connections from private properties to the public sewers are built and maintained by the property owner. This work is done by licensed drain layers under the supervision of the Supt. of Sewers and in accordance with lines and grades laid out by the Engineering Department.

The maintenance problems of the city's sewer system, therefore, pertains solely to the public sewers and its manholes, regulators, catch basins and pumping stations.

Structure Records

The physical structural records of the Worcester System are recorded in various standard ways. A "Manhole Book" is prepared which indicates by streets the location and characteristics of the various sewers. A companion "Inlet Book" records the location of the Y inlets which are provided for house and property service connections. A complete individual record showing the location, physical features and operating data of the seven thousand catch basins is kept. These are filed alphabetically by streets and serve as reference and statistical records of their operation and maintenance.

Except for individual sewer plans prepared for purposes of sewer betterment assessment purposes, the department has no complete small scale plans of its several sewers. All design, plans, profiles and field notes pertaining to the sewers are prepared by the City Engineering Department. Constant changes in street surfaces, adjustments of street boundary lines, alterations in adjoining property lines and buildings have produced a very considerable loss in the value of these original plans.

For the past two years manhole locations have been

BAY STATE ROAD — KIND OF SEWER: Sanitary Inlets

	SIZE	SIDE OF STREET	HOUSE OR LOT	DISTANCE	DIRECTION	M. H. NO.	DISTANCE FROM	ST. LINE	DISTANCE	DIRECTION	LINE OF HOUSE
	6"	W	Lot	28.3	N	51	Maplewood				
	6"	E	"	33.6	N	51					
	6"	W	"	80.75	S	1					
**	6"	E	"	74.95	S	1	**Stakes lost by foreman				
	6"	E	#113	48.25	S	1			6.0	N S	Ho.
	6"	E	#109	12.0	N	1	Bay State		10.8	N S	Ho.
	6"	E	#105	86.7	N	1			16.8	N S	Ho.
	6"	W	Lot	91.6	N	1					
	6"	E	#101	132.6	N	1			10.2	N S	Ho.
	6"	W	Lot	137.6	N	1					
	6"	E	Ho.	104.6	S	2			11.6	S S	Ho.
	6"	W	Lot	100.4	S	2					

BAY STATE ROAD — KIND OF SEWER: Surface Inlets

SIZE	SIDE OF STREET	HOUSE OR LOT	DISTANCE	DIRECTION	M. H. NO.	DISTANCE FROM	ST. LINE	DISTANCE	DIRECTION	LINE OF HOUSE
6"	E	#109	12.0	N	1			10.8	N S	Ho.
6"	E	#105	86.7	N	1			16.8	N S	Ho.
6"	W	Lot	91.6	N	1					
6"	E	#101	132.6	N	1			10.2	N S	Ho.
6"	W	Lot	137.6	N	1					
6"	E	Ho.	104.6	S	2			11.6	S S	Ho.
6"	W	Lot	100.4	S	2					
6"	E	"	19.9	S	2					
6"	W	C.B.	63.6	N	2					
8"	E	C.B.	67.1	N	2					
6"	E	Lot	19.9	N	2					
6"	E	Ho.	105.6	N	2			13.1	S N	Ho.

A Page From the "Inlet Book" Covering Sanitary and Storm Sewer on the Same Page

checked, and new ties established. Small scale (40 feet to 1 inch) sectional maps of the city are being prepared showing street and property boundaries together with these public sewers. These will be filed in convenient map drawers and with a complete system of card files by streets, a convenient reference can be made to these plans. (See print of the 24 x 20-inch standard plan.)

Cleaning and Complaint Records

Imposed on the wall of the administrative office of the department are two identical plans of the city's street layout. These plans are drawn to a scale of 400 feet to 1 inch. On one of these plans is shown the complete public sewer layout—sanitary, surface and combined sewers. The other plan is made up to indicate only the surface water system with the location of all catch basins. These two maps serve as a comprehensive visual picture of the city's sewer system and serves for many quite evident public as well as departmental purposes. A particular use is made of the map devoted to surface sewers with the catch basin location. This consists of various colored pins which designate the month when the basin was cleaned; and also, by a distinctive pin, evidence of trouble as set forth in complaints. This visual picture of the cleaning of catch basins is of great value to the administrative office.

Sewer Sizes

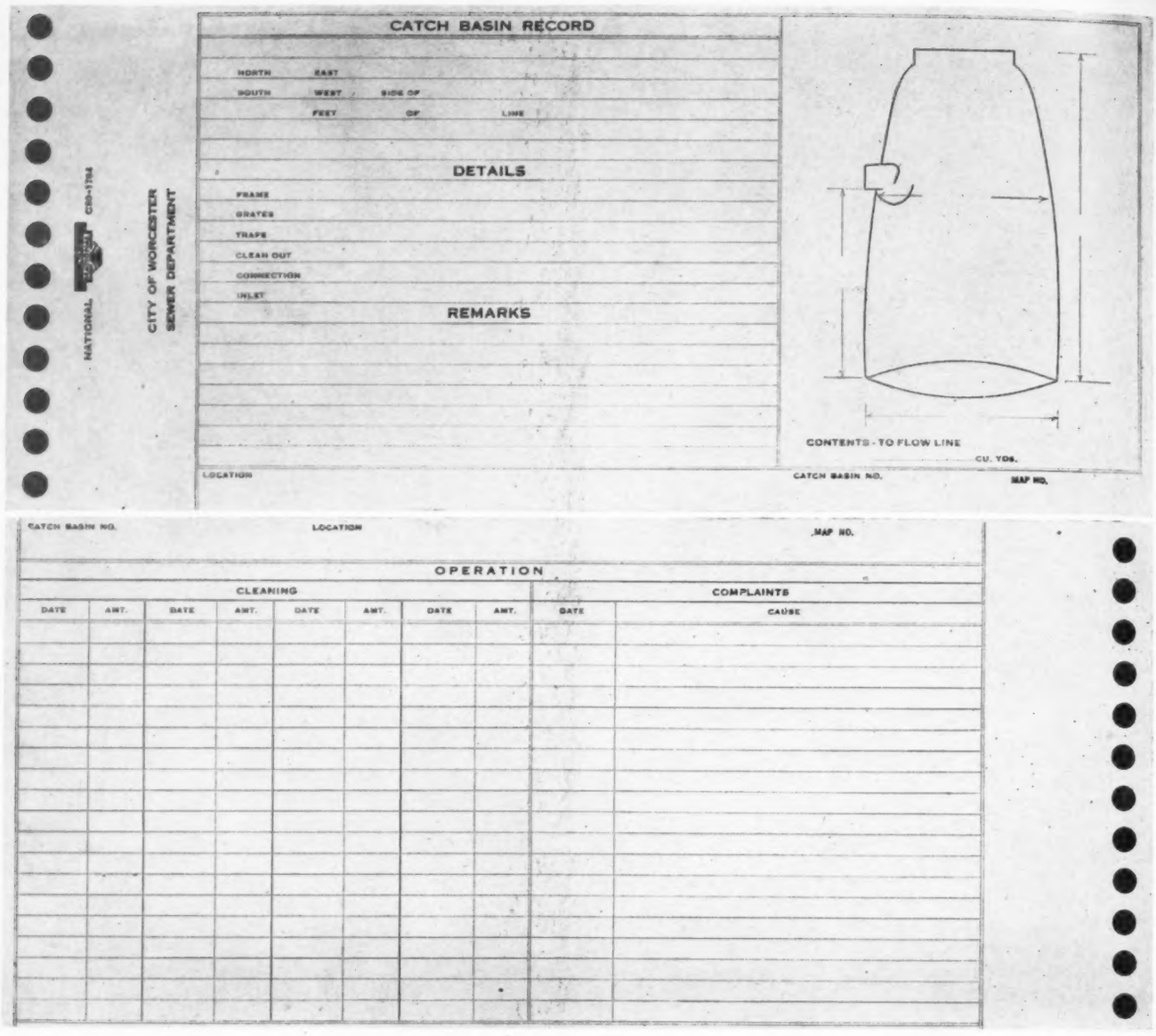
Worcester has long established a minimum size for sewers—namely, 8-in. on sanitary lines and 10-in. on surface lines. Six-inch pipe is used for all house connections. Grades ample to maintain velocities sufficient to prevent the accumulation of solids on the invert and sides of a sewer are always used. Velocity grades of approximately 2 feet per second have been found sufficient to preclude depositions in the sewers.

It has been the experience of the writer that less frequent trouble arises due to under capacity in sanitary sewers than is found from this fault in surface sewers. The empirical formula used in the design of sanitary sewers, based on anticipated normal development of the district sewered, seems to have produced less error in judgment. The frequent overload placed upon surface sewers should not always be charged against the designer, especially when it is appreciated that early day conditions could not possibly forecast the almost complete evolution in conditions as they now exist. It is never contended that surface sewers should be designed to accommodate the very extreme storms, often called "cloud bursts." It has developed that with completely sealed street surfaces, with adjacent lands covered either, with buildings, sealed drive ways, or paved areas, the percentage and rapidity of the run-off, even in ordinary

BAY STATE ROAD — SANITARY ON WEST

M. H. NO.	DEPTH	ELEVATION WATER LINE	DISTANCE	DIRECTION	M. H. NO.	STREET	DISTANCE FROM	ST. LINE	DISTANCE	DIRECTION	LINE	STREET	SIZE	BUILT	LATERAL SEWER	SIZE	DEPTH	ENTERED
1	9.93	668.334	163.95	N	San. 51	MaplewoodTrunk	26.0	E	30.7	S	N	Monterey(Ext)	10"	1928	Monterey Rd.	8"		1926
2	9.49	673.444	275.4	N	1	Bay State Rd.	24.8	E	23.6	N	S	Brighton Rd."	8"	"	Brighton Rd.	8"		1928
3	10.25	676.975	276.4	N	2	" " "	25.2	E	23.6	N	S	Coventry Rd.	"	"	Coventry Rd.	8"		1929
4	8.35	681.085	276.4	N	3	" " "	25.2	E	24.9	N	S	Bellingham Rd.	"	"	Bellingham Rd.	8"		1929
5	7.98	684.435	277.5	N	4	" " "	25.0	E	26.3	N	S	Devens Rd.	"	"	Devens Rd.	8"		
6	7.80	686.085	182.6	N	5	" " "	25.2	E					"	"				
7	8.45	690.745	228.5	N	6	" " "	24.5	E					"	"				
8	8.20	692.795	97.55	N	7	" " "	24.9	E	58.8	S	S	(Looking east) Clark St.	"	"				

Portion of a Page From the Manhole Record Book. This One Is the Sanitary Sewer in Bay State Road. An Accompanying Sheet Reveals the Same Data on the Parallel Storm Sewer



CATCH BASIN RECORD

NORTH EAST
SOUTH WEST SIDE OF
FEET OF LINE

DETAILS

FRAME
GRATES
TRAPS
CLEAN OUT
CONNECTION
INLET

REMARKS

CITY OF WORCESTER
SEWER DEPARTMENT

NATIONAL CBS-1764

CONTENTS - TO FLOW LINE
CU. YDS.

LOCATION
CATCH BASIN NO.
MAP NO.

CATCH BASIN NO. LOCATION MAP NO.

OPERATION

CLEANING								COMPLAINTS	
DATE	AMT.	DATE	AMT.	DATE	AMT.	DATE	AMT.	DATE	CAUSE

Catch Basin Job Record Blank (Front and Rear)—Inspection, Cleaning, Complaints.

rainfalls, is extremely high. Where storm water sewers in the early development of an area were quite adequate, the changed conditions of the surface of the water sheds has indicated that a larger water way is necessary.

Manholes

Manholes should always be located wherever there is a change in grade or alignment. These should be built at intervals of not over 300 ft.; and, 200 ft. is better. The average cost of a manhole placed at such minimum intervals does not increase the construction cost in any such proportion as will its location at an excessive interval forever effect maintenance problems. The earlier sewers in the Worcester system unfortunately did not always follow this plan. Occasions have occurred where the sewers have had to be uncovered in order to remedy some trouble.

Noisy manhole covers are a general nuisance. They not only cause annoyance to the citizen but are a source of maintenance expense, if neglected. They will eventually destroy the seat and necessitate a renewal of the entire frame. Not only is there involved the cost of the frame but the labor expense of replacement and the repair cost of the street surface makes it an expensive item. Asphalt and other cushioning products are quite successfully used to prevent this annoyance. Worcester's castings are of heavy design with provisions made for cover and seat to be machined when needed.

Manhole steps are necessary for use in entering a manhole. They are usually of 1-in. iron rods built into the brick work. The early practice of providing projecting bricks for steps has long been abandoned. Flexible ladders made of rope sides and wooden rungs are a standard part of the maintenance crew's equipment.

The experience with lamp holes with their many abuses and their lack of real efficiency has caused them to be ruled out in the Worcester system. The slight saving in cost over a regular manhole does not warrant their installation.

Catch Basins

Local conditions—of climate, of topography, of road surface, and particularly the system of surface sewers—their course and final outlet—all have a very important bearing on, the need for, and the physical characteristics of, catch basins. All catch basins in Worcester are trapped, not entirely for purposes of preventing nuisance from sewer gases but, to protect entrance of silt into the

sewers. Worcester's standard catch basins, as built today, have a maximum depth of 9 feet below the grating with a cross section averaging 4 ft. 6 in. by 4 ft. 9 in. The outlet is usually placed 3 ft. 6 in. below the grate. Provisions are thus made for a catchment area to accommodate a very considerable volume of material. The average construction cost of the Worcester basin is, for material—brick, cement, sand, castings, etc., $125.00; for labor, trucking and other charges $150.00 to $200.00.

Cleaning Equipment

For many years the cleaning of the city's catch basins was done by hand labor, the material being cast from the basin to the street and then loaded into carts and hauled to the nearest available dumps. In 1919 the department designed and had built several machines for this purpose. The equipment consists of an orange peel bucket, with a capacity of one and one-half cubic feet, suspended from a crane, the whole mechanism being mounted on a two-ton auto truck. The power for raising the bucket and that required for operating a compressor which furnishes air for opening and closing the bucket is obtained from the auto engine. The mechanism is so arranged that the operator, who also drives the truck, can easily and quickly control all movements of the bucket, swinging it by means of a crank with worm gear attachment. One helper stands over the basin opening, guiding the bucket somewhat, and at times swinging it from side to side, when in the basin, in order that it may pick up the material to the best advantage. This machine is designed to fill carts or trucks, as the case may be, rather than to fill the body of the truck itself as practiced in some cities. Operating in this manner the machine is kept steadily at work excavating the material in the basins and does not consume time in trips to and from the dump. (See illustrations.)

The cleaning of these basins is done by a crew consisting of a foreman, two operators of the catch-basin machines (drivers of the trucks), two bucket men, one sweeper man, one dump man and four to six 1½-ton dump trucks. The debris cleaned from the basins is trucked to public dumps located in outlying sections of the city. The continuous operations of this maintenance work is particularly necessary, especially in a community where heavy showers and rains are frequent. The policy of large catchment area in the Worcester basins helps to overcome some of the difficulty occasioned by the lack of funds and infrequent cleaning.

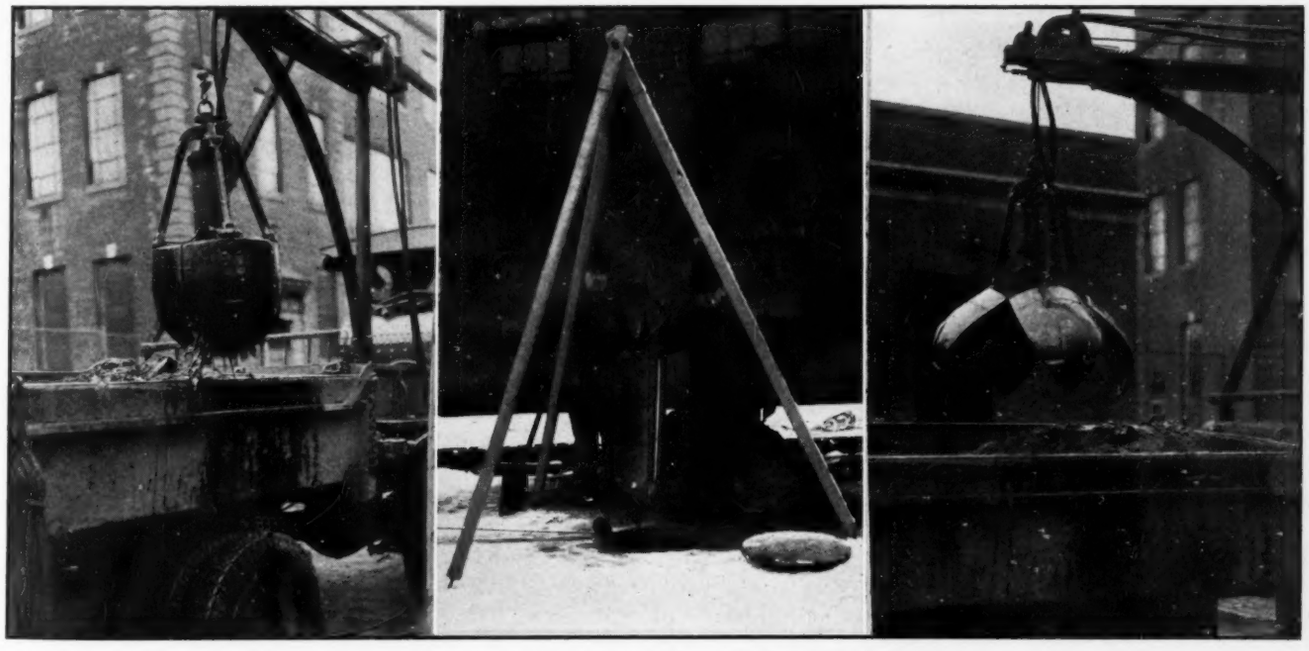
A typical year's operation in this work shows 6,328 basins cleaned with a removal of 14,102 cubic yards of material at an approximate cost of $4.40 per catch basin, or approximately $2.00 per cu. yd. of material removed. There has never been any mosquito nuisance resulting from stagnant water in Worcester's basins. Occasionally, during long dry periods, foul odors have been complained of which are promptly overcome by cleaning and flushing.

Sewer Cleaning

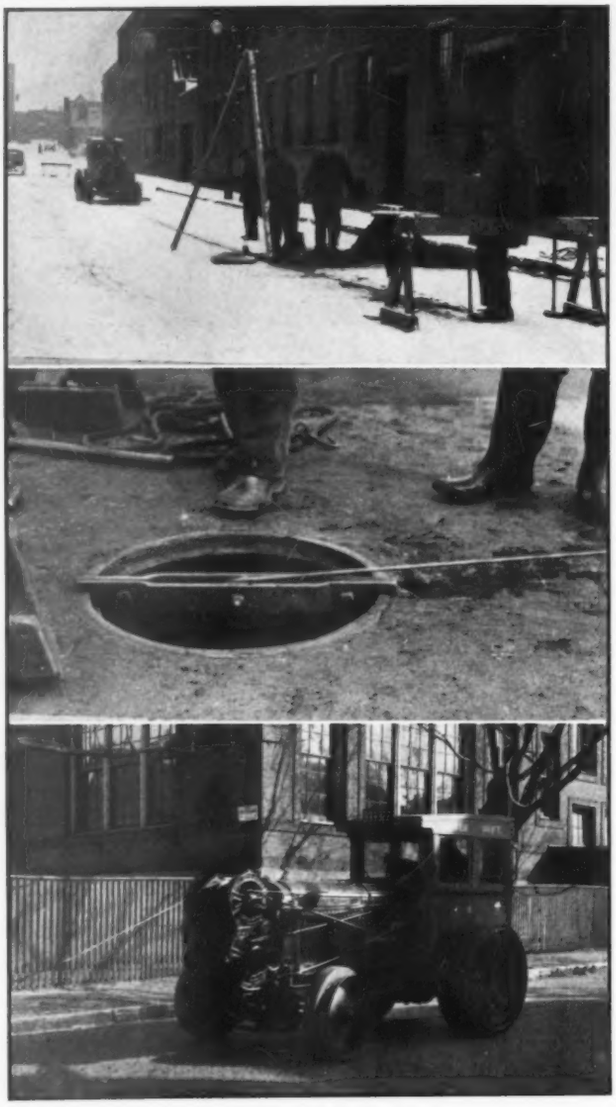
The cleaning and scraping of sewers is handled by a crew consisting of a foreman, three laborers, a Fordson tractor with operator. Bell shaped scrapers and special buckets, of a size suitable to the particular sewer, are pulled through from manhole to manhole by means of an endless cable operated from the tractor. Suitable pulleys and frames are inserted at the foot of the manhole and on the surface of the street, making it possible for the bucket to be drawn through the sewer and raised to the street surface. The bucket is then emptied by opening a lid or door. As is common with most sewer systems, the entry of tree roots causes considerable maintenance trouble. By use of an expanding root cutting tool these are removed, using the same method as outlined above in cleaning. This operation is never a cure for the trouble. It alleviates the blockage for a period, only to eventually recur. (See illustrations.)

Poor sewer joints obviously are to be avoided. Constant care in workmanship will accomplish good joints regardless of the particular type of jointing material used. Worcester has tried various types. At the present time a jointing compound, poured hot into the joint, is used with marked success.

A sewer, in the eyes of the general public, is regarded as a receptacle for any kind of material which can be disposed of through its connection. Even though ordi-



(1) Back to Back Are These Two Trucks—One with the Derrick and Orange Peel Bucket Cleaning the Catch Basin, the Other Hauling Off the Debris. (2) The Tripod Rig with a Cleaning Scoop Going "Head First" Into a Large Sewer. (3) From the Crane-Truck the Orange Peel Is Opened and Closed by Compressed Air to Fill the Coming-and-Going Dump Trucks.



Sewer Cleaning and Root Cutting in Worcester. (1) *Cleaning Tractor Operating Between Manholes.* (2) *Street Level Pulley Attachment for the Smaller Drains.* (3) *Business End of Cleaning and Utility Tractor.*

nances are formulated to prevent these abuses their violation is difficult to prevent. Obstructions occur and many maintenance ills arise therefrom. Particular trouble comes from the misuse of street catch basins. It seems to be an American custom to consider them as a depository for anything that can be thrust through the gutter mouth; and, "out of sight—out of mind."

There are four sections of the city which are below the reach of the gravity facilities of the sewer system. The sewage from these sections flows to pumping stations where automatically controlled pumps raise it to the gravity system. At each of these pumping stations duplicate units of pumping equipment are installed. Each unit is capable of handling the normal load at the station, which permits continued service in case of repairs.

The Worcester Sewer Department is concerned, in addition to the maintenance of its sewer system and appurtenances, with the operation of the Sewage Treatment Plant and the construction of new sewers. Its entire personnel in addition to the superintendent consists of 157 employees. These are normally distributed as follows:

Administrative and general service force	35
Maintenance force	20
Sewage treatment force	15
Construction force	87
Total	157

General

While this discussion pertains more especially to maintenance it is pertinent to observe these customs in the Worcester organization which are allied to maintenance.

Administrative and general service facilities are available for all activities of the department. The department equipment and mechanical apparatus is serviced and is furnished to whichever force requires it. The personnel of the Maintenance Division consists of a general foreman, under whom suitable units of workmen perform the emergency work as it occurs. The organization for catch basin cleaning and scraping of sewers has been outlined. When the latter operation is not necessary, other repair work to sewers, manholes and catch basins is accomplished using units suitable for the task. The operation of the four pumping stations, and their supervision and maintenance, is handled by three employees. There are also two employees whose duties include the inspection and maintenance of the storm water regulators mentioned earlier in this discussion.

Emergency Service

During the normal working hours of the department emergency service is always at hand. After these hours the continuance of this service is provided for by two shifts of two employees. The public expects prompt and satisfactory service at all times, and every complaint is promptly attended to.

The Department's equipment and tool supplies are ample and commensurate with the services required. Motor equipment, pumps, special sewer flushing equipment, small tools and miscellaneous materials are available at short notice. Safety belts, gas detectors, small portable air blowers and first aid equipment are provided for any emergency.

Records pertaining to the physical properties of a sewer system are of prime importance. These, as have been outlined, are essentially necessary in the maintenance and operation of the sewers. The importance of maintaining records pertaining to complaints is strongly stressed in the Worcester Sewer Department. Occasions can arise where claims of negligence can be refuted by the full evidence recorded on these complaint slips.

Costs

The maintenance of a sewer system involves many different factors. Unit costs covering such operations are mainly valuable to indicate comparisons between similar expenditures in other years. The pumping costs per million gallons are distinctive only for that particular installation. The cost per linear foot for cleaning one particular sewer has no significant relationship to the costs of cleaning some other sewer. Catch basin cleaning costs do lend themselves to some analysis. However, even in this operation, the local conditions are so variable that even those are of questionable value.

The production of satisfactory service to the public involves expenses which are difficult to measure by any convenient yard stick. Appropriations for such services are always too small. Worcester, with a population of approximately 190,000 spends less than 50 cents per capita per year on a sewer system estimated to have cost considerably over twelve million dollers. These do not appear to be excessive when considering the value of

Name _____ Week Ending _____

Job MAINTENANCE Foreman _____

	Sat.	Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Total	Account No.	
									151	Sewer Repairs
									152	Sewer Cleaning
									153	Repairs to Catch Basins
									154	Cleaning Catch Basins
									155	Freezing Catch Basins
									156	Repairs to Manholes
									157	Regulators
									158	Work on Brooks and Rivers
									189	Other Sewer Main.
										Accounts Receivable
										Conn. Catch Basins

Maintenance Record for Distribution of Costs

the service performed. "Out-of-sight—Out-of-mind"—but maintenance never ceases.

The appended tabulation reveals expenditure records during the past five years in Worcester.

WORCESTER SEWER DEPARTMENT
Records of Expenditures (to the nearest dollar)

	1933	1934	1935	1936	1937
Miles of sewers	367	373	378	385	391
Sewer repairs	$ 1,563	$ 3,098	$ 5,488	$ 2,587	$ 7,849
Sewer cleaning	9,575	4,587	9,307	7,838	9,520
Catch Basins:					
Repairs	2,419	3,616	6,837	4,271	4,753
Cleaning	25,019	27,288	27,707	26,018	29,928
Freeing	3,128	9,968	8,300	14,589	10,089
Repairs to manholes	.....	.....	2,965	862	1,832
Maint. of regulators	4,010	4,672	5,755	5,404	5,698
Maint. of brooks and riv.	2,416	10	262	983	603
Maint. and operation of pumping stations	16,108	18,365	18,898	16,164	16,880
Totals	$64,237	$71,605	$85,521	$78,714	$87,154

▼

Contributions of the Sanitary Engineer to the New York World's Fair

By Homer N. Calver*

New York World's Fair 1939, Inc.
New York City

THE Medical and Public Health Building at the New York World's Fair next year will present a dramatic portrayal of the complete story of man and his health, including the contributions to modern public health standards and practices by the branches of science and industry concerned with water supply, sewage disposal, garbage disposal, health and housing, milk and food control, and the many other fields where the engineer and technician are bulwarks in man's fight against disease and the hazards of life.

Three main divisions of the building—the Hall of Man, the Hall of Medical Science and the Hall of Public Health—will reveal how modern medical knowledge and public health practices are preventing disease and gradually increasing man's life span. More than 350 distinguished medical men, sanitary engineers, health leaders and experts in allied fields comprise the World's Fair's Advisory Committee on Medicine and Public Health.

The entire presentation will be unique in that it will be the first time in the history of fairs and expositions that exhibits are being developed entirely from the standpoint of subject matter rather than on the basis of exploitation of products or organizations. It is believed that this approach not only will have greater interest for the Fair visitor, but will redound to the greater benefit of sponsoring agencies. These agencies will receive generous recognition by individual sponsorship plaques over sections and exhibits, and through the Professional Club which will be established as common meeting ground for professional men and sponsors, and sponsors' representatives.

To date, sixteen outstanding public health organizations, foundations, individuals and commercial firms have taken nineteen sections for a total of 11,200 square feet of exhibit space. Probably because of the wide and basic interests served by this building, the demand for space has been greater than in a majority of the other Fair-built buildings. Sponsors for the Sanitary Engineering Section and related exhibits in the Hall of Public Health include:

The Dorr Company, water supply, sewage treatment and waste disposal;
John B. Pierce Foundation, hygiene of housing;
Cherry-Burrell Corporation, milk control;
West Disinfecting Company, occupational infections and sanitation.

Water Supply and Sewage Disposal

The section devoted to water supply and sewage disposal is being planned on a basis of 1,000 square feet. It will be part of the main Engineering Section of approximately 2,500 square feet where the related exhibits of milk and food control, housing and air hygiene, occupational infections and sanitation, etc., will be located. The Dorr Company is the major sponsor of the Sanitary Engineering Section which will embrace water supply, sewage treatment, waste disposal, municipal cleansing and swimming pool sanitation.

Extensive preliminary studies have been made by engineering and sanitation experts of the subcommittee on Sanitary Engineering for the exhibit plan of the section. The "Water-Cycle" approach may be utilized in telling the story of the exhibit, tracing water from its sources through its purification and delivery to the home, office and factory; its many uses and consumption; its outcome as spent-water supply (sewage or industrial wastes); its treatment and partial purification and return to the source, where nature completes the job of undoing what man has done.

Deputy Health Commissioner Sol Pincus of the City of New York, is Chairman of the Subcommittee on Sanitary Engineering, and the other members are: Anthony Anable, Engineer, The Dorr Company; J. L. Barron, Westchester County Health Department; Walter D. Binger, Bureau of Public Works, Borough of Manhattan; L. V. Carpenter, Professor of Sanitary Engineering, New York University; C. A. Emerson of George Gascoigne and Associates, Consulting Engineers; Linn H. Enslow, Editor, WATER WORKS AND SEWERAGE; Frank W. Herring, Executive Director, American Public Works Association; C. A. Holmquist, New York State Department of Health; Harry E. Jordan, Executive Secretary, American Water Works Association; Arthur P. Miller, Sanitary Engineer, United States Public Health Service, Abel Wolman, Chief Engineer, Maryland State Department of Health.

[We are repeating the list of members of the Sanitary Engineering Committee in this issue because of the fact that the list printed in our March issue was incomplete. —Ed.]

*Director of Public Health Exhibits.

TESLA PORTAL CHLORAMINATION STATION

Installed for the Control of Biological Slime Growths in the Hetch Hetchy Aqueduct of San Francisco

By G. E. ARNOLD
Chief Water Purification Engineer, Water Department, San Francisco

The Author

THE San Francisco Water Department has recently placed in operation what is reputed to be the world's largest chlorine-ammonia treatment plant. This plant, located at the eastern end of the Coast Range Tunnels of the Hetch Hetchy Aqueduct, is designed to treat Hetch Hetchy water at this point for disinfection, but more importantly for the control of filamentous biological growths which have developed in the tunnels along this section of the Aqueduct. The station has a capacity of 2,000 pounds of chlorine and 400 pounds of ammonia per day and involves a number of unique features.

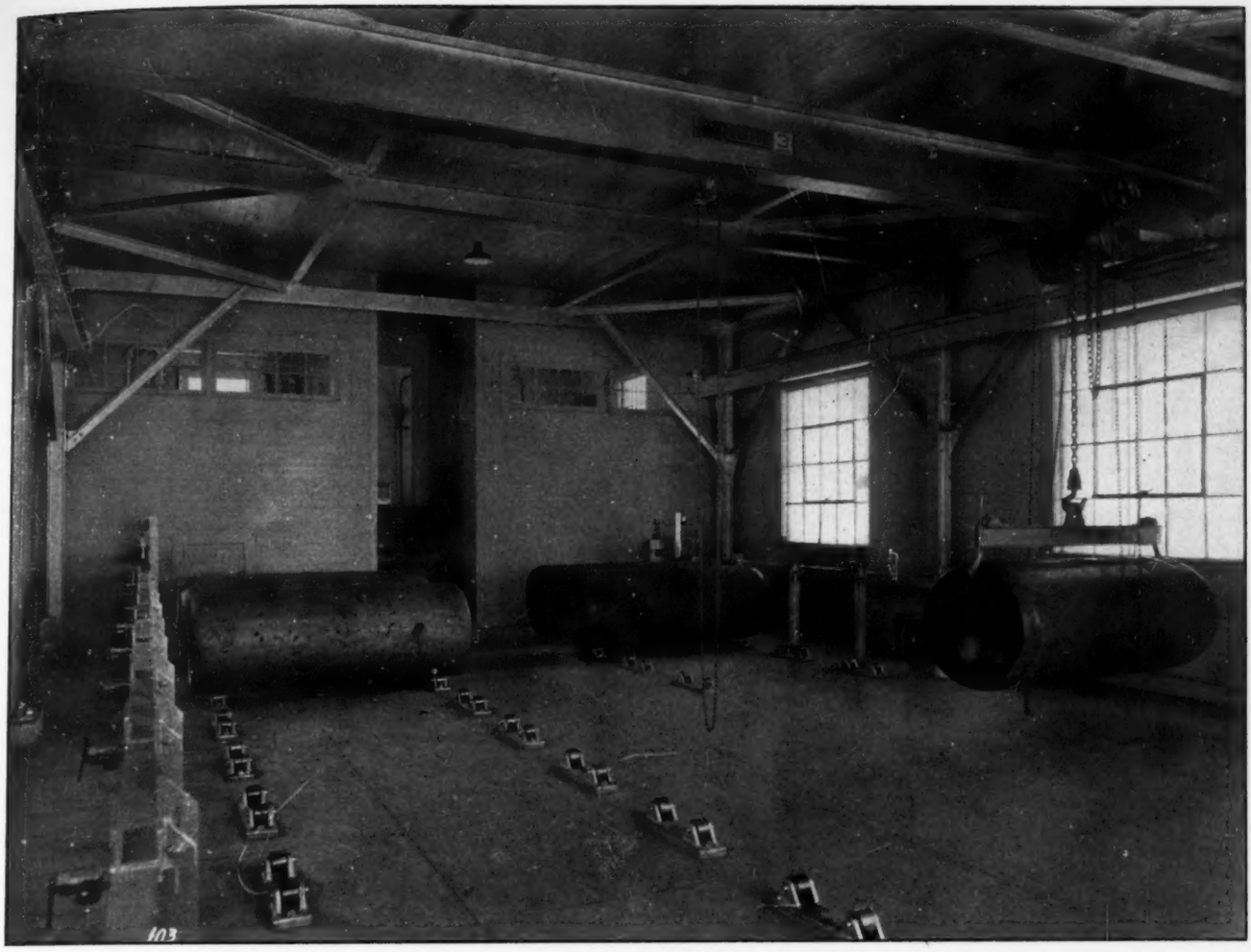
Hetch Hetchy Water Supply System

Hetch Hetchy water is impounded behind the O'Shaughnessy Dam and in Lake Eleanor on the Tuolumne River in the High Sierras. The head waters are 200 miles from the center of San Francisco. The water, upon being released from storage, flows down a natural river channel to Early Intake where it is diverted into the mountain division tunnels. It flows for 20 miles underground, passes through Priest regulating reservoir, and then drops 1300 feet through steel penstocks to Moccasin Powerhouse where the normal flow of 400 million gallons a day generates 100,000 horsepower. Below the powerhouse, most of the water is diverted back into the river. The portion of the water brought on to the city through the aqueduct passes through 18 miles of foothill tunnels and 47 miles of steel pipe across the San Joaquin Valley to Tesla Portal where it enters the Coast Range Tunnels. These latter are concrete lined tunnels, 28 miles long, and bring the water to Irvington, on the east side of San Francisco Bay. From Irvington, the water flows through 25 miles of steel pipe, part of which is submarine section under San Francisco Bay, and discharges into Crystal Springs Reservoir about 20 miles South of San Francisco. From this point, the water is brought into the city through a separate transmission and distribution system.

Biological Slime Growths Develop in Coast Range Tunnels

During the construction of the Coast Range Tunnels, considerable quantities of ground water were en-

Tulsa Portal Chlorination Station. On the Edge of Arid San Joaquin Valley, Chlorination and Ammoniation House in Center Rear; Attendant's Home on Right; Pump Station on Left.



Container Room with Chlorinator—Ammoniator Room Beyond. Note the Roller Saddles for Containers; the Protected Twin Gas Manifolds; the Pressure Reducing Valves and Alarm at the Far End of Each. Chlorine on Left; Ammonia on Right.

countered, some of which continued to seep into the tunnel after the lining operations were completed. Within a few months after the system was placed in operation, a biological slime growth developed in the Bay Crossing pipe lines. The growth had the appearance of light-brown gelatinous coating which covered the interior of pipes carrying this water. Investigation disclosed the same condition throughout most of the Coast Range Tunnels but no trace of the growth was found in the aqueduct above this tunnel. The growth was heaviest at the points of inflow of ground water seepage; this seepage proving to contain certain bacterial organisms among which were the iron bacteria, *crenothrix*, and the sulphur bacteria, *beggiatoa*. This growth in the tunnels depleted the dissolved oxygen content of the water and at times produced noticeable taste and odor. It also materially reduced the carrying capacity of the pipelines.

Studies of Control Measures

Various means of controlling the growth were studied in the laboratory and in the field. Copper sulphate, lime, chlorine, chlorine and ammonia, were applied in different ways. An experimental plant was constructed at the Alameda Creek crossing of the aqueduct, where eight four-inch pipes, each 300 feet long, were laid and subjected to a flow of the tunnel water. Varying amounts of copper sulphate, lime, and chlorine-ammonia were applied to these pipes to determine the best type of treatment to eliminate or check the troublesome growths. Larger quantities of chemicals were also applied to different points on the aqueduct as an experimental measure. Hydrated lime was added to the water, filling one section of the Coast Range Tunnel, in a sufficient quantity to raise the causticity of the water to pH 10. This water was held in the tunnel for four days in contact with the growth but no beneficial results could be observed.

From the above studies, it was concluded that the chlorine-ammonia process was the most satisfactory treatment for the elimination of this growth. Following this, an ammonia machine was installed in the Calaveras Chlorinating Station and treatment was applied to a portion of the aqueduct from this station. Similar treatment was given at the Irvington Chlorinating Station. These treatments immediately produced a noticeable decrease in the growth in the affected portions of the lines and tunnels. Over a period of weeks, the growth steadily diminished until it entirely disappeared. With continuing treatment no recurrence has taken place, whereas, the growth in the untreated portions of the tunnels continued undiminished.

Tesla Station

Since these growths were more or less prevalent throughout the Coast Range Tunnel, it was decided that the most satisfactory place to treat the water would be at the point where it entered this tunnel, namely, at Tesla Portal. The station consists of a group of buildings including the chlorinator house in which is located the chlorine and ammonia machines, the chlorine and ammonia

containers, and the connecting piping. There is a pump house in which are located two electric pumps and the switchboard for the station. A residence for the operator, and a garage are also provided. Two fifteen thousand gallon water tanks are located on a hill just west of the station, as shown in the accompanying photograph.

The chlorinating equipment consists of two one thousand pound per day capacity, manually-controlled, W. & T. master vacuum chlorinators. The ammonia machines consist of two, two-hundred pound per day capacity, manually-controlled, W. & T. ammonia machines with injectors. This equipment is housed in the west end of the chlorinator building in an insulated room. The floor of the chlorinator-ammoniator room is about five feet above the floor of the container room.

Container Handling

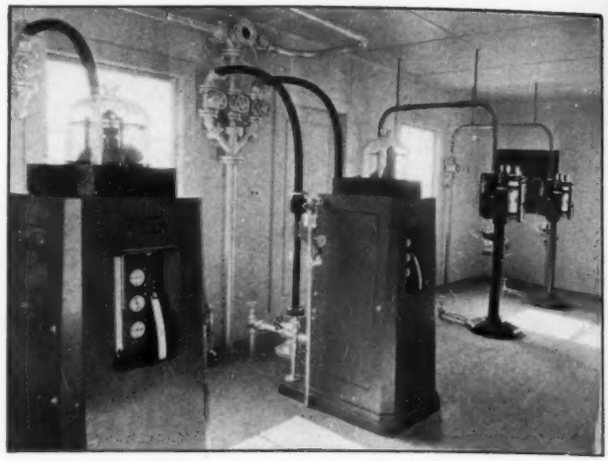
The container room is approximately 28 by 40 feet, has a concrete floor with arrangement for connecting ten chlorine containers and four ammonia containers to the pipes simultaneously. There is also storage capacity for fifteen additional containers. Chlorine and ammonia are both received in the same size container, the chlorine container holding 2000 pounds of liquid chlorine, the ammonia container holding 800 pounds of anhydrous ammonia. An overhead crane facilitates the placing of containers in the proper position for the gas headers. A set of rollers is cast into the concrete floor for each cylinder so that the tanks may be rotated to get the valves in the proper position after the container is placed with the crane. The accompanying photograph shows the layout with several containers in place and one on the crane.

Gas headers are in duplicate, with one header having a pressure reducing valve and an alarm assembly. For the chlorine gas header, the pressure reducing valve is set to deliver chlorine to the chlorinators at 25 pounds and the gas pressure operated alarm switch on the low pressure side of the reducing valve is set to ring when the pressure drops below 25 pounds. With this setup, full cylinders are attached to the portion of the header upstream from the pressure reducing valve. After alarm indication, that the pressure in this header has dropped to 25 pounds, the operator can switch the connections from the nearly empty containers to the lateral or second header that connects to the chlorine gas line downstream from the chlorine pressure reducing valve. This permits complete emptying of the containers in a relatively short time. If the operator so desires, he can switch over to a full bank of containers when the alarm rings and can then completely empty the original set of tanks at a later and more convenient time. There are connections on each of the headers for five containers. A similar arrangement is used on the ammonia lines with the exception that the pressure reducing valve is set for 50 pounds and the alarm switch is set accordingly. The gas headers are protected by steel angles placed over the piping to prevent them from being damaged in handling the containers.

The pump building contains two direct-connected, turbine-type pumps, each delivering 100 gallons per minute directly into the storage tanks on the hill. The operation of the pumps is automatically controlled by float switches in the tanks.

Solution Distribution

The chlorine and ammonia solutions are carried from the machines to the point of application through specially designed rubber hoses. The ammonia hose is 2-inch inside diameter and the chlorine hose 4-inch inside diameter. Hoses are in fifty-foot lengths, coupled together



Twin Chlorinators (1000 *lbs./day each*); *Twin Ammoniators* (200 *lbs./day each*). *Note Twin Ejectors and Water Feed Lines.*

with hard rubber nipples placed inside the hose and clamped by four bands on the outside of the hose at each joint. The chlorine diffuser consists of an eight-foot length of rubber-lined and rubber-covered steel pipe, in which a series of small holes have been drilled. The diffuser is placed on the floor of the tunnel a few feet downstream from the junction of the tunnel with the pipeline from which the water enters the tunnel. The ammonia diffuser consists of a stainless steel pipe bent to conform to the inside diameter of a 72-inch steel pipe. The stainless steel pipe is perforated with a series of small holes on the inside circumference through which the ammonia solution is discharged at the point upstream from the point of chlorine entry.

The station has been in operation only a few months and during this time has treated a relatively small flow of water. Inspection of the tunnel discloses a marked decrease of the growth, particularly at the eastern end near the treatment plant. With larger flows of water, even better results are anticipated. The normal treatment has involved between one and two parts per million of chlorine, employing a one to five ammonia-chlorine ratio—i.e., 0.2 to 0.4 ppm. ammonia (NH_3) dosage. The operation of the plant has been satisfactory and no difficulties have been encountered with the equipment.

Transportation of Supplies

The Tesla Portal Station is located eight miles from the nearest railroad and is about thirty miles from the plant of the Great Western Electro-Chemical Company, which supplies the chlorine and ammonia. On this account it proved economical to purchase an eight-ton motor truck for hauling chemicals to the station. This truck is equipped with special racks for carrying four one-ton containers at one time. When the station is operating at capacity, it will be necessary for this truck to make two or three trips each week. Hauling is done directly from the chemical plant as this eliminates the necessity of loading and unloading railroad cars and providing a siding and crane facilities at the railroad.

[Note: In the Reference and Data Section of this same issue is to be found a similar story by J. Walter Ackerman. It reveals the effectiveness of chlorination at Utica, N. Y., in controlling iron bacteria and maintaining pipeline capacity due to the suppression of nodulation previously induced by such iron-monger bacteria. The graphic record of friction loss is the all-telling picture, before and since the treatment was started four years ago.—ED.]

ACTIVATED SLUDGE PLANT OPERATION

Some Basic Principles and Operating Hints on the Process

By W. H. WISELY

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The Author

IN sewage treatment the settleable matter is removed by sedimentation and the resultant sludge is "rotted" in digestion tanks or lower compartments of the Imhoff tanks, whichever is in use. The fine solids which will not settle and those dissolved in the water are more difficult to remove. Since these make up about 66 per cent of the total objectionable organic matter, in many cases they must be almost entirely removed to avoid damaging the outlet stream. The activated sludge process is one method employed to remove these latter types of solids.

In the process, microscopic plants and animals are put to work to render the organic matter unobjectionable. Oxygen is necessary to the existence of these tiny bacteria and other organisms, therefore, provision is made for the application of air (containing 20 per cent oxygen) in the aeration units, these units being a fundamental part of the plant.

Biological, physical and chemical actions are all involved in the process. Some of the objectionable matter is probably actually consumed by the organisms but it is generally believed that their most important function is to produce substances of a chemical nature which react with amazing speed to oxidize, mineralize or otherwise convert the objectionable matter to substances not objectionable. Therefore, chemicals need not actually be added at any part of the process as Nature provides for their manufacture. It is important that it be kept in mind that oxygen is essential to the life of the organisms, just as it is to human existence.

What Is Activated Sludge?

If a tank of sewage is liberally aerated for several days by mechanical splashing or by actually blowing air through it, visible, brownish, feathery flakes or "flocs" form and the aerated sewage will loose its identifying odor. If the addition of air is then stopped, it will be found that these flocs settle out quite rapidly and leave a very clear and odorless liquid above. The brownish floc is called "activated sludge" and when examined under a microscope, it is found to comprise a slimy, sponge-like mass upon which there are many queer-shaped, moving "bugs." These "bugs" bring about "oxidation" by consuming and chemically changing the sewage as described previously.

Each individual floc is a small "world" in a universe of sewage. If suitable living conditions are maintained, the "bug" population of the floc passes through the life cycle, raising "buglets" and continuously working to break down the objectionable matter in the sewage. Also, the flocs are the battleground for constant warfare wherein some types of organisms combat other types for supremacy. If the aeration tanks are kept in proper condition, the organisms that are most desirable in the treatment of sewage are helped to outnumber their foes.

When allowed to settle, the flocs drop downward to the bottom, sweeping out any remaining objectionable matters that may yet be suspended. This action is like "putting a filter through the sewage" if the floc is considered as a moving filter.

What is activated sludge? It may be defined as the rapidly settling sludge obtained from sewage which has been agitated in the presence of abundant oxygen and is composed of clumps of jellylike or amorphous matter upon which numerous microscopic plants and animals live.

How the Process Is Applied

Obviously it is not possible to retain and aerate for several days, all of the sewage received at a sewage treatment plant. In order to speed up the action so as to obtain the required removal of organic matter in a shorter time and in smaller tanks, some of the activated sludge is continuously returned to the inlet of the aerating tank from the "final tank" in which it is settled out. This always provides a larger number of tiny "workmen" in the aeration unit, which the operator must keep in condition so they can function. The returned sludge "seeds" the settled sewage so that the work of purification is begun at once.

As pictured in the accompanying flow sheet (Fig. 1), the raw sewage passes through the screens and primary settling tank where the settleable solids are removed. Then a part of the activated sludge taken from the final settling tank is added to the settled sewage and the mixture is aerated for the proper length of time during its passage through the aeration tanks. The aerated mixture, often called "mixed liquor," is then passed through the final settling tank where the activated sludge separates from the clear water which overflows continuously to the outlet stream as plant effluent.

Naturally, some of the activated sludge must be wasted or the operator would find himself in the position of the bride who tried to boil a pound of rice in a quart pan. The usual method of wasting excess sludge is to discharge it to the raw sewage when it is settled out in the primary tank and pumped to the digester with the primary sludge. In other plants the

This elementary discussion of the activated sludge process is not intended for experienced sewage plant operators who have had technical training. The material has been taken from articles by the writer in past issues of "The Digester,"—the worthy quarterly bulletin issued by the Division of Sanitary Engineering of the State Department of Public Health designed to promote more efficient sewage treatment plant operation.

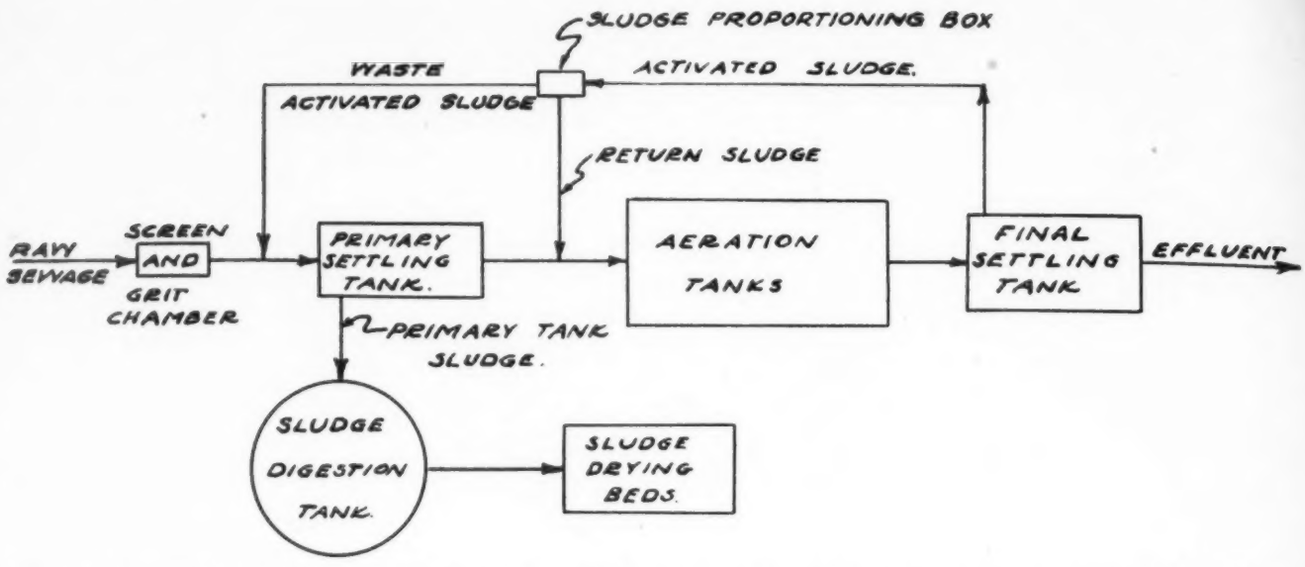

Fig. 1—Diagrammatic Flow Sheet of a Typical Activated Sludge Plant. In the Larger Plants Vacuum Filters May Replace the Sludge Drying Beds. The Sludge "Cake" from the Dewatering Filters May Be Dried and Burned in an Incinerator, or Utilized as a Fertilizer Base in Part or in Whole

excess activated sludge is thickened in small separate tanks and transferred therefrom to the digester direct.

Air may be supplied in the aeration tanks in a number of ways. At some plants, air under pressure is forced through porous plates or tubes which cause small bubbles to pass upward through the mixed liquor. This method, called the "diffused air" type, makes oxygen available from the bubbles and by the circulation across the surface. A mechanical aerator manufactured by the American Well Works is very similar in operation to the diffused air system but the air bubbles are introduced as the liquor splashes into a central cone from which a pump forces the frothy "mixed liquor" to the bottom of the tank, affording circulation and contact with the entrained air.

The Simplex aerator, by beating and splashing the tank surface with a vaned wheel, puts atmospheric air into the mixed liquor and also brings about circulation by lifting the "mixed liquor" from the bottom of the tank upward to the surface through a center draft tube. The Chicago splash type aerator circulates the "mixed liquor" at a very high rate with a pump so that air is introduced from the atmosphere by the violent splashing created on the splash plate and at the surface.

It will be noted that all of these methods provide for constant circulation and mixing of the working sludge and sewage, as well as for the application of oxygen. It is also evident that much depends on the operator in order to obtain best results from an activated sludge plant. The delicately balanced biological process must be carefully maintained through his adjustments and regulation of air and sludge return to the aerating units.

Requirements of the Process

A properly operating activated sludge plant must afford:

1. Adequate oxygen. This is supplied in a diffused air plant by air compressors and in a mechanical aeration plant by the special aeration machinery.
2. Sufficient time of contact for the working organisms in the activated sludge to complete their task of cleaning the sewage. "Aeration periods" of 5 to 6 hours are common in diffused air plants; in mechanical aeration plants 8 to 10 hours.
3. Thorough and continuous mixing and agitation of the mixture of activated sludge and sewage. This is ordinarily accomplished by the same equipment that supplies air or oxygen at the aeration tanks.

Factors Influencing Process

A knowledge of the various factors which may affect operation of the activated sludge process is essential to proper control in the plant. In this discussion it must be kept in mind that an adjustment at one point in the plant may require further regulation at several other places because all of these items are closely meshed together.

Load on Aeration Units

Naturally, satisfactory operation of the aeration units cannot be expected if the sewage load is greater than the sewage treatment works capacity. When such is the case, everything possible should be done to increase primary settling tank efficiency and the sewage flow to the aeration tanks and returned sludge should be reduced to give a proper load on those units until additional plant structures can be added.

At many plants, the nature of the sewage flow is such that the rate of flow and strength of sewage varies between wide limits during the day. At some places, the strength of sewage at 3 p. m. is 20 to 30 times as strong as at 3 a. m. This condition is difficult for the plant operator because constant attention is necessary to see that a serious upset does not occur. Unfortunately the increase in volume accompanies increase in strength of sewage and thus the loading is pyramided.

The load on some plants is very markedly affected by industrial wastes and the nature of these problems varies widely. Some wastes, particularly those containing oil, grease, sugars and strong acids or alkalies should not be treated by the activated sludge process unless effective preliminary treatment is given. Large quantities of oil or grease seem to coat the flocs and do not give the organisms sufficient contact with the sewage. Wastes containing sugars promote the thread-like fungus growths which cause one type of "bulking." Strong acids and alkalies or poisoning metallic salts destroy the natural functioning of the microscopic organisms in the activated sludge. The wastes from breweries, distilleries, milk products plants, textile mills, canneries, gas plants, electroplating works, and packing plants are

among those which may be troublesome. The municipality usually has full authority to compel an industry to provide preliminary treatment of its waste, or if necessary, to exclude a particularly troublesome waste from the sewer system.

The supernatant liquor from improperly operating sludge digestion tanks is frequently responsible for aeration difficulties. In most plants supernatant liquor is wasted back to the inlet of the primary settling tank to be passed through the treatment works with the regular sewage flow. The quality of supernatant liquor depends upon the condition of the digester, being relatively clear and free of suspended matter when digestion is normal and especially where stage digestion is employed. A poor supernatant should be temporarily disposed of on a sludge bed, or to a lagoon, if plant piping permits. Supernatant is dangerous when black in color, has a foul, sour odor, contains considerable suspended matter, and a pH below 6.6. Addition of lime to a poor supernatant during return is helpful. Regardless of whether good or bad, always return supernatant to treatment at a slow, uniform rate.

Quantity of Activated Sludge Solids

This item is probably the most important of all those involved in activated sludge plant operation. The amount of suspended solids carried in the mixed liquor must be sufficient to produce the desired purification in the aeration period available, but must be low enough to give the most economical usage of air. Aeration solids concentration is intimately associated with aeration period and air supply.

If samples were collected at various points in an aeration tank so that the extent of purification after 30 minutes, 1 hour, 2 hours, etc., up to 8 hours aeration could be determined, a curve similar to that shown in Figure 2 could be drawn. With a normal concentration of aeration solids, the curve will show 70-80 per cent of the total purification taking place in the first hour of aeration.

Too much emphasis cannot be given the value of the suspended solids determination on the mixed liquor. This figure gives an indication of the number of working organisms which are present in the tanks. Every operator must determine, by intelligent trial and error methods, the concentration of mixed liquor (suspended solids) at which the plant functions best and most economically under every condition to be met.

The amount of solids which can be carried is limited only by the air supply. If too great a solids content is present, the air requirement will exceed the supply and bulking will result. On the other hand, purification takes place more rapidly and more completely when a high solids content is maintained. The proper suspended solids concentration for any plant must be fitted to the sewage load, aeration period and the air supply—all at the same time. When one of these three conditions is changed, the solids content of the mixed liquor must be adjusted to the change. The present tendency is to carry 1,500-2,500 p.p.m. of aeration solids in diffused air plants and 300-1,000 p.p.pm. in mechanical aeration plants.

Where the strength of sewage varies widely through the day or week, sufficient aeration solids must be present to meet peak loads. Think of the aeration solids as "workmen"; retain as many as are necessary to do the work as it comes, yet not too many as they all require air to stay in condition. Too low an aeration solids content leaves purification work unperformed during the stay of the mixed liquor. From the standpoint of economy, avoid carrying excess solids just because the air supply permits. The excess workmen are merely "shovel-leaners" in such a case and no real good is accomplished.

The amount of activated sludge carried in the plant (mixed liquor) is controlled by the extent of wasting excess sludge, usually to the inlet of the primary settling unit. Always waste sludge at a slow, uniform rate. If sludge is not wasted in this manner, it may not settle out completely in the primary tank and will pass right through into the aerators again. Being in poor condition after passing through the primary tank it usually causes trouble. The mixed liquor solids content of the aerator is the best guide as to when and how much sludge to waste. If not equipped to make this determination, the operator must be guided by the sludge settling test, good judgment and a Divine Providence. When the sludge is in good condition, from 10 to 15 per cent settled sludge after settling a sample of mixed liquor for one hour is usually satisfactory.

Quantity of Air

Nearly all of the effective air applied to an aeration tank is used up by the activated sludge proper, and only a fraction is directly consumed by the organic matter in the sewage being treated. Clearly then, the principal factor governing the amount of air necessary to maintain good conditions in the tank is the amount of activated sludge being carried during aeration, and more especially its activity. For instance, 2,000 p.p.m. suspended solids in the mixed liquor might require oxygen at a rate of over 100 p.p.m. per hour, whereas 500 p.p.m. of suspended solids might require only 30 to 40 p.p.m. of oxygen per hour for good purification.

The easiest and most certain way to determine whether or not the proper amount of air is being applied is by means of the dissolved oxygen test on samples of the mixed liquor taken at progressive points through the aeration process. Ordinarily, dissolved oxygen will be found to drop sharply at the inlet end and to increase gradually to about 4 or 5 p.p.m. before the mixed liquor leaves the aeration tank. It may be possible that no dissolved oxygen will be found at the very beginning of the period, but some should be present throughout the unit at least 75 per cent of the time. It is sometimes possible to make several adjustments in the air supply each day to maintain sufficient but economical usage of air.

The air supply in the diffused air plant is controlled by the regulation of valves on the air piping. In a mechanical aeration plant, the air supply is governed by the number of units in service, adjustment of the aeration machinery, or by using time switches on the aerators to automatically give any desired operation and rest cycle.

Septic conditions in the aeration tank will result if the air supply is insufficient. Where the supply is inadequate, even during part of the day only, bulking of the sludge and its loss over the weir of the final tanks usually results.

It has been found that more air is consumed at the beginning of the aeration period than at the end. Accordingly, if the plant arrangement permits, adjust the aeration equipment so that the air supply tapers off as the aeration process lengthens. Be guided in such adjustment by the dissolved oxygen content through the aerators.

Excessive use of air, besides being wasteful, may also impair purification in the same way as does an overlong aeration period.

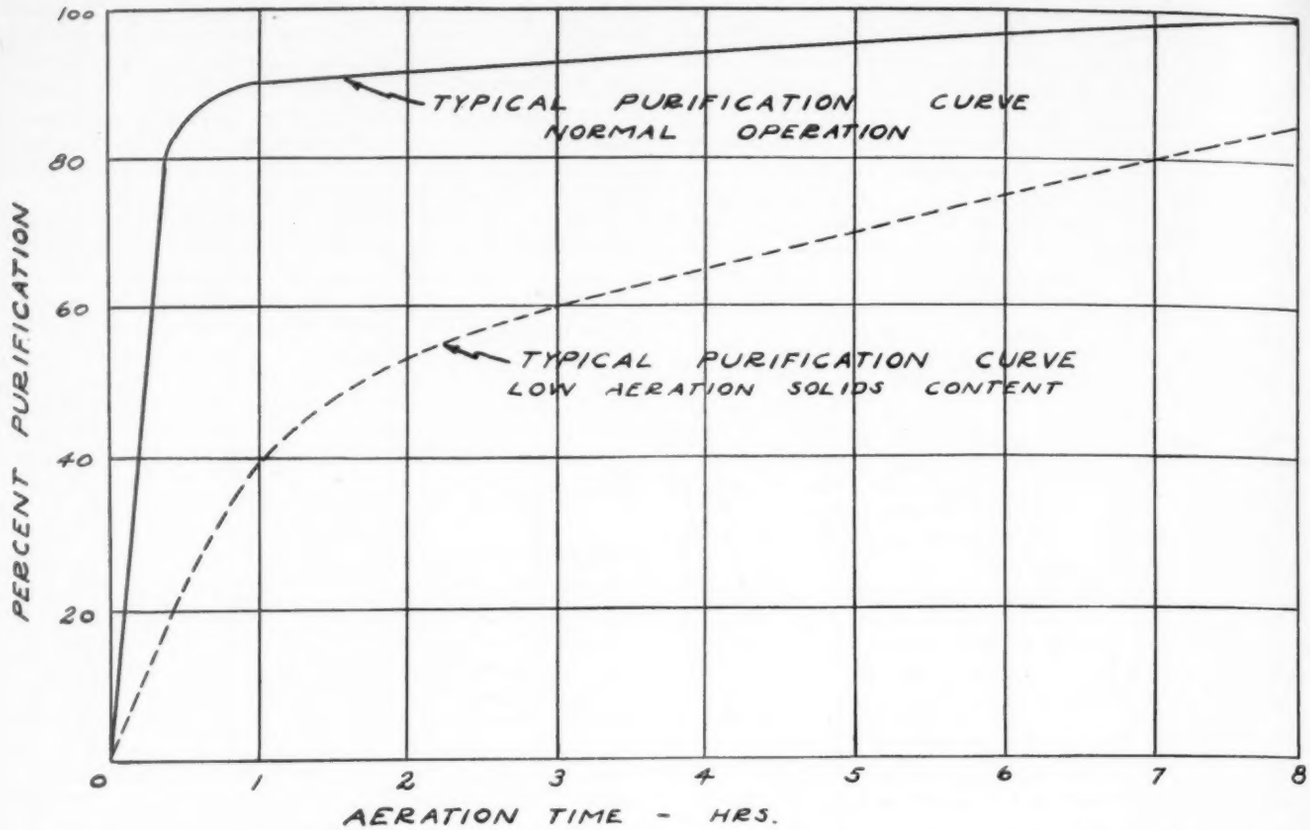

Fig. 2—Curves Revealing Typical Relationship Between Time of Aeration; Solids Carried in the Aeration Units (Mixed Liquor), and Degree of Purification Resulting at the End of Various Aeration Periods.

Aeration Period

From examination of Figure 2 it might appear that the aeration process could be stopped after 2 or 3 hours, since very little additional improvement in purification takes place from then on. This, however, cannot be done as the activated sludge must be reconditioned or regenerated after it has worked so hard to store up organic matter at the very beginning of the aeration period. Also, the treated sewage is given a "finish" at the end of the period where introgenous matter is converted to mineralized nitrates.

If the aeration period was shortened the sludge would be returned before it was completely regenerated and the purification would gradually be reduced, depending on the amount of suspended solids being carried in the mixed liquor. The sludge flocs would become bulky and would settle poorly as a result of this lack of proper after-conditioning.

Calculate the aeration period in the plant under varying conditions of flow and then note the lengths of time which are necessary to give good results during the various seasons of the year. Adjustment of the aeration period is made by placing units in or out of service, which obviously should not be done too frequently. At most plants, the only adjustment of aeration period is made in changing from summer to winter conditions or vice versa.

If a strong, concentrated sewage is received during part of the year, it will be found that a longer aeration period will be required because there is more work to be done by the working organisms and they must be allowed more time to get it done. They must also be given more time to regain their vigor in the presence of air.

Care should be taken in studying the plant to make sure that there is no short-circuiting of flow through the aeration units. Even though the proper number of units may be in service, under-aeration may result if the flow takes a "short-cut" through only a part of the tank. Look for short-circuiting in the aerators and if such is found it may be corrected by the careful location of baffles in the tank or by a rearrangement of inlet or outlet gates.

An overlong aeration period may also affect plant operation but this condition is rather rare. If the detention period in the aerators is too long the sludge may become light yellow in color and will leave many tiny particles dispersed in the water overlying the final settling tank sludge blanket and in the effluent.

Where a highly concentrated, variable strength sewage is received, "re-aeration" of the return sludge is sometimes practiced. In this method of operation, one aeration tank is used to aerate the return sludge only so that it will be thoroughly reconditioned before being added to the settled sewage again. Present tendency is to consider the use of sludge re-aeration only for strong, variable loads. The application of sludge re-aeration to most mechanical aeration plants seems to be subject to some question, probably because the concentration of solids in the re-aeration units is beyond the re-aerating ability of such units.

Rate of Sludge Return

Theoretically, it would seem desirable to return the activated sludge as soon as possible from the bottom of the final settling tank to the inlet of the aeration tanks, but some plants use the final tank as a sludge reservoir. The accumulated layer of activated sludge in the bottom of the final settling tank is called a "sludge blanket" and the present tendency is to minimize this accumulation as much as possible and "store" sludge in the aerating units only.

Where a sewage of highly variable strength is received, it is usually desirable to return more activated sludge during the peak strength in order to provide more working organisms at the time more work is to be done. In such a plant a 2 or 3 feet sludge blanket might be carried in the final settling tank during most of the day so that these extra workmen will be available for service when the peak comes.

The rate of activated sludge return is closely related to the aeration period, a high rate of return reducing the aeration time and a low rate of return increasing it. On the other hand, the high rate of return brings the sludge back into the presence of the air more quickly, thus maintaining the activity of the sludge.

There is a definite danger in maintaining too thick a sludge blanket because if the sludge is held in the final settling tank too long without oxygen being present, septic action may take place in the bottom of the tank which will cause large chunks of dark colored sludge to rise to the surface where they break up and pass out in the plant effluent. Rising sludge in the final tank is therefore an indication that opportunity is being afforded for septic action to take place. A stale return sludge may also be a contributing cause of sludge bulking as will sludge which has passed through the primary tank.

Temperature

Ordinary hot weather temperatures do not seriously affect the activated sludge process directly, although high temperatures together with low sewage flows may cause the raw sewage to be stale and septic at some plants. Increasing the aeration period by placing an extra unit in service, if available, and increasing the rate of activated sludge return is helpful under such conditions since the high rate of return has a tendency to dilute and freshen the sewage flow.

Extremely low winter temperatures also affect the process. When the temperature in the aeration tanks is below about 8 degrees C., the activity of the sludge is reduced as shown by the settling characteristics of the sludge. At such times considerable fine, dispersed floc may be found in the plant effluent. Since the activity of the working organisms is affected, some deterioration in the quality of the effluent also results.

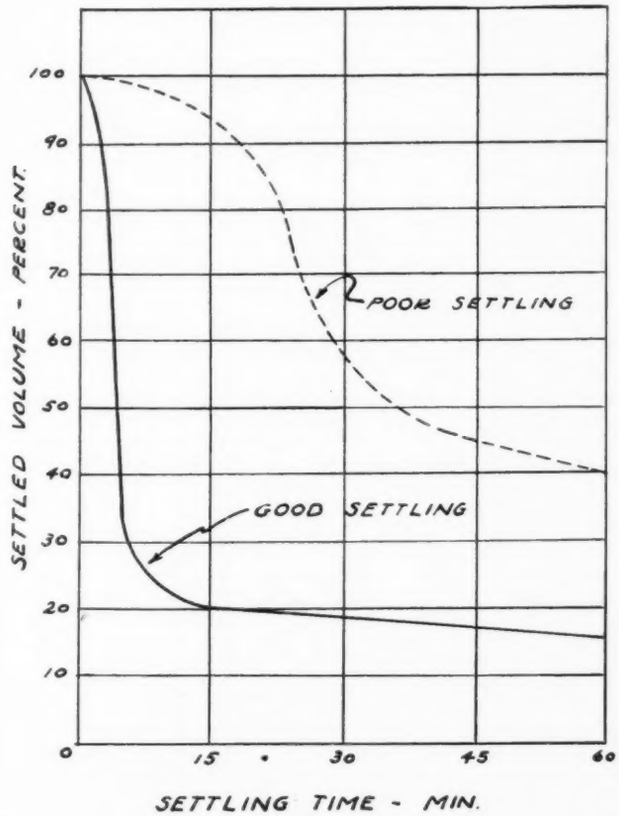

Fig. 3—Curves Depicting the Settleability of Good and of Poor Aeration Solids. (It is Important to Keep a Close Check on the Trend of Sludge Condition with the Settling Test. Along with It the Dissolved Oxygen Content of the Mixed Liquor Should Be Watched to Preclude Sludge Bulking—See Text.)

Operation Difficulties

The most common way in which trouble is indicated in an activated sludge plant is by "bulking" of the sludge. The sludge will be found to settle poorly, frequently passing over the weirs of the final settling tank instead of settling to the bottom. The sludge floc at such times will bulk large and fluffy, whence the term "bulking." Obviously such a condition upsets the entire treatment process and reduces purification efficiency.

Bulked sludge usually results from an unbalanced condition in the aeration tanks so that the microscopic life in the activated sludge is affected, causing the floc to swell and lose density. Another common form of bulking results from the growth of an undesirable thread-like fungus which may cause an otherwise good sludge to settle poorly.

Besides bulking, trouble may come in the form of septic conditions in the aeration tanks, greatly reducing the efficiency of treatment. At such times the sludge will be black and malodorous, will settle poorly, and the plant effluent will be unsatisfactory.

When trouble comes, seek cause first. The cause of bulking may be an excessive load on the plant, an industrial waste, a poor digester supernatant, an inadequate aeration period, insufficient air supply, too high or too low an aeration solids content, a stale return sludge or what have you. Permanent correction depends on eliminating the cause.

Some remedies that have proven helpful in correcting bulking are offered for consideration. Most of them are believed to be best applicable to cases of builking which involve the presence of the thread-like fungus growths or "filaments." Caution is suggested in using chemicals for controlling bulking as excessive dosages may be harmful to the desirable working organisms in the sludge. Try to correct the bulking by operation adjustments first. Then:

Chlorine applied to the return sludge at a dosage between 0.7 and 7.0 p.p.m. (based on return sludge flow) has been found helpful. Start with a low dosage rate and gradually work up to preclude over treatment.

Lime added at inlet to aerators to raise pH in tanks to 8.6-8.8 for 4 to 6 hours has controlled bulking. Begin adding lime as soon as bulking appears imminent. Application as a solution of hydrated lime is recommended.

Copper sulfate applied to the aeration tank influent at a dosage of 1.0 p.p.m. is reported to be helpful at times.

Ferric chloride added to the raw sewage has given some success. A dosage of 54 to 66 pounds per million gallons of sewage has been recommended. The application of ferric chloride to the return sludge has also given favorable results.

When the aerator contents turn septic, again seek the cause! The same items listed above as causes of bulking should be checked for possible correction.

If the aerators are badly septic, it is usually impos-

sible to revive good conditions without emptying or sterilizing the tanks and building a new activated sludge. When septic action is just beginning, the addition of lime to the aerators to raise the pH above 7.0 may help. By-passing the sewage flow around the aerator (except for sludge return) for a short time may speed up the reconditioning of the activated sludge.

As has been stated previously, the most common cause of this trying condition is the overlong retention of sludge in the final tank before return and insufficient aeration at the inlet end of the aeration units. The sludge blanket should be lowered or air increased to correct this. At some plants, rising sludge has occurred in the spring and fall of the year without apparent reason, but this is usually of short duration.

A rather rare but quite interesting condition causing floating sludge in final clarifiers has developed in a few plants in hot weather. The gnat-like chironomus fly (a water supply pest) has been known to lay its eggs on the aeration tank walls, the larvae passing into the final clarifier, gather sludge flocs about them to form cylindrical balls about one inch in diameter and two inches long. These float on the tank surface—to break up when touched and the sludge passes off with the plant effluent.

A European plant reports that the insect is effectively controlled without affecting the activated sludge by a single dose of pyrethrum powder at a rate of 1 pound per 1,200 gallons of mixed liquor. As the preferred egg depository seems to be an aeration tank wall where there is very little splashing or turbulence, thorough cleaning of such places with a direct application of a strong pyrethrum solution is suggested.

Summary of Important Operation Control Items

1. Observe how the sewage load varies at the plant through the day and with the season of the year. Determine what adjustments in air and sludge return are necessary to meet these variable conditions.

2. Know what industrial wastes are represented in the raw sewage. Much work, expense and worry may be avoided by seeking a little cooperation (friendly, if possible; otherwise compulsory) from an industry.

3. Watch that digester supernatant! A place to dispose of it when temporarily bad is invaluable—only don't discharge it to the stream! Be careful at all times when returning supernatant to treatment—do it slowly and evenly.

4. Study the aeration tanks for short circuiting. Make sure that all of the available aeration period is being used.

5. Power to supply aeration (often better than 90 per cent of all power used) costs the municipality good money. Use sufficient air in the right place but don't be wasteful.

6. Establish the proper aeration solids concentrations to meet all conditions imposed on the plant. Don't keep any more working organisms on the "payroll" than necessary, but keep enough on hand to meet peak loads. This is a most important operating consideration in preserving balance.

7. Always waste sludge slowly and evenly—don't waste in heavy "slugs." The same may be said of supernatant liquor wasting.

8. Don't let septic conditions take place in the final settling tank. It is usually better to return sludge at a liberally high rate than too slowly. Don't let too heavy a sludge blanket accumulate.

9. When difficulties arise, seek the cause first! Then correct procedure may be accomplished much more quickly and effectively.

72 FIRMS TO EXHIBIT AT NEW ORLEANS

To date, April 7th, the following 72 firms have taken exhibit space at the American Water Works Association Convention to be held April 25-29th at the Hotel Roosevelt in New Orleans.

EXHIBITOR	ADDRESS
The Addressograph Multigraph Co.	Cleveland, O.
Activated Alum Corp.	Baltimore, Md.
American Cast Iron Pipe Co.	Birmingham, Ala.
American City Magazine Corp.	New York City, N. Y.
Art Concrete Works	Pasadena, Calif.
The Atlas Mineral Products Co. of Pa.	Mertztown, Pa.
Badger Meter Mfg. Co.	Milwaukee, Wis.
Birch Mfg. Co.	Chicago, Ill.
Buffalo Meter Co.	Buffalo, N. Y.
Builders' Iron Fdy.	Providence, R. I.
Cardon-Cadillac Corp.	Birmingham, Ala.
The Central Foundry Co.	New York City, N. Y.
The Chapman Valve Mfg. Co.	Indian Orchard, Mass.
Chicago Bridge & Iron Co.	Chicago, Ill.
Cliffs-Dow Chemical Co.	Marquette, Mich.
Crane Co.	Chicago, Ill.
Darco Corporation	New York City, N. Y.
Darling Valve & Mfg. Co.	Williamsport, Pa.
DeLaval Steam Turbine Co.	Trenton, N. J.
S. R. Dresser Mfg. Co.	Bradford, Pa.
The Dorr Company, Inc.	New York City, N. Y.
Eddy Valve Co.	Waterford, N. Y.
Engineering News-Record	New York City, N. Y.
The Farnam Brass Wks. Co.	Cleveland, O.
Flexible Sewer Rod Equipment Co.	Los Angeles, Calif.
The Ford Meter Box Co.	Wabash, Ind.
General Paint Corp., Hill, Hubbell & Co. Div.	Cleveland, O.
The Fred W. Hanks Co.	Cleveland, O.
Hays Mfg. Co.	Erie, Pa.
Hersey Manufacturing Co.	Boston, Mass.
Homelite Corp.	Port Chester, N. Y.
Hydraulic Development Corp.	New York City, N. Y.
Industrial Chemical Sales Division, W. Va. Pulp & Paper Co.	New York City, N. Y.
International Filter Co.	Chicago, Ill.
Johns-Manville	New York City, N. Y.
The Kennedy Valve Mfg. Co.	Elmira, N. Y.
Koppers Co.—Western Gas Div.	Fort Wayne, Ind.
Lead Industries Association	New York City, N. Y.
The Leadite Company	Philadelphia, Pa.
Lock Joint Pipe Co.	Ampere, N. J.
M & H Valve & Fitting Co.	Anniston, Ala.
McWane Cast Iron Pipe Co.	Birmingham, Ala.
Mueller Company	Decatur, Ill.
National Cast Iron Pipe Co.	Birmingham, Ala.
National Meter Co.	Brooklyn, N. Y.
National Water Main Cleaning Co.	New York City, N. Y.
Neptune Meter Co.	Long Island City, N. Y.
The Pardee Engineering Co.	Long Island City, N. Y.
The Permutit Co.	New York City, N. Y.
Phoenix Meter Corp.	Prince Bay, S. I., N. Y.
Public Works Magazine	New York City, N. Y.
Pittsburgh Des Moines Steel Co.	Pittsburgh, Pa.
Pittsburgh Equitable Meter Co.	Pittsburgh, Pa.
%Proportioneers, Inc.%	Providence, R. I.
The Pitometer Company	New York City, N. Y.
Rensselaer Valve Co.	Troy, N. Y
Ross Valve Mfg. Co., Inc.	Troy, N. Y.
L. A. Salomon & Bro.	New York City, N. Y.
Simplex Valve & Meter Co.	Philadelphia, Pa.
The A. P. Smith Mfg. Co.	East Orange, N. J.
S. Morgan Smith Co.	York, Pa.
R. W. Sparling	Los Angeles, Calif.
Thomson Meter Corp.	Long Island City, N. Y.
United States Steel Corp.	Pittsburgh, Pa.
Vogt Manufacturing Co.	Louisville, Ky.
Wailes Dove-Hermiston Corp.	New York, N. Y.
Wallace & Tiernan Co., Inc.	Newark, N. J.
Water Leak Detector Co.	Columbus, O.
Water Works Engineering	New York City, N. Y.
Water Works & Sewerage	New York City, N. Y.
R. D. Wood Company	Philadelphia, Pa.
Worthington-Gamon Meter Co.	Harrison, N. J.

Meet the "WATER SMELLER"

Water Smeller
He Tests Water by Sense of Smell
This Man Tests Water By Unusual Sense Of Smell
WATER SMELLER STARTS SURVEY
Americans' Olfactory Powers Rated as Most Discriminating
TYRONE CHEMIST HONORED FOR ABILITY
Henry Laughlin Becomes Na- Expert 'Water Smeller'
"WATER SMELLER" NAMED FOR CITY
HIS NOSE KNOWS, SO HENRY LAUGHLIN HAS WATER SMELLER JOB
Human Nose Can Detect Even The Faintest Odors
Water Smeller
Perhaps the most unusual occupation of Henry Laughlin of Tyrone, Pa., in the United States is that of Henry Laughlin as the official "water smeller" for a firm ma
CHEMICAL INDUSTRIES, JULY 1, 1937
First U. S. "Water Smeller"
His Job Is Smelling Water
BAD WATER FLAVOR DRIVES GOOD COOK TO DISTRACTION
First "Water Smeller"

This demonstrates the value of publicity created for the purpose of arousing the interest of Mr. John Public in the important functions of water departments.

HENRY LAUGHLIN (Water Smeller) will be on hand at The American Water Works Association Convention at New Orleans. Arrangements for the future can be made at that time to carry out tests in your own laboratory showing the effectiveness of AQUA NUCHAR for taste and odor removal.

●

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DIVISION OF WEST VIRGINIA PAPER & PULP COMPANY

230 Park Avenue, New York City

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MANUFACTURERS OF NUCHAR ACTIVATED CARBON

Your GUARANTEE

OF STRENGTH & EFFICIENCY

1. Correct design—All parts interchangeable.
2. Efficient operation — Simple, yet rugged construction.
3. Longer life—Less maintenance cost.
4. Full compliance with latest specifications of the American Water Works Association.
5. Approved and Listed by the National Board of Fire Underwriters' and Associated Factory Mutuals Fire Insurance Companies.
6. Prompt shipment of your orders.
7. What more could you ask?

Fig. 29H

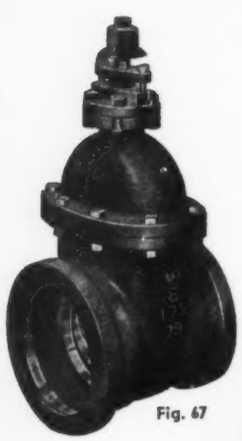


Fig. 67

Fig. 72-73

M & H VALVE & FITTINGS COMPANY

ANNISTON, ALABAMA

SALT for your table—cast iron pipe for your underground mains—nothing takes their place. Both are basic and indispensable as they have been for centuries. Both are better products today than they were 20 years ago.

If you demand *proved* long life and low maintenance cost that result from effective resistance to corrosion — assured safety margins for impact, beam load and crushing stresses—with permanently tight joints—then you will agree that *nothing takes the place of cast iron pipe.* Some materials meet some of these requirements but only cast iron pipe meets them all.

CAST Q IRON

Look for the "Q-Check" registered trade mark.
Cast iron pipe is made in diameters from 1¼ to 84 inches.

THE STANDARD MATERIAL FOR UNDERGROUND MAINS

Putting down a cast iron water main to serve for a century. Original cast iron mains are still in service in more than 200 cities.

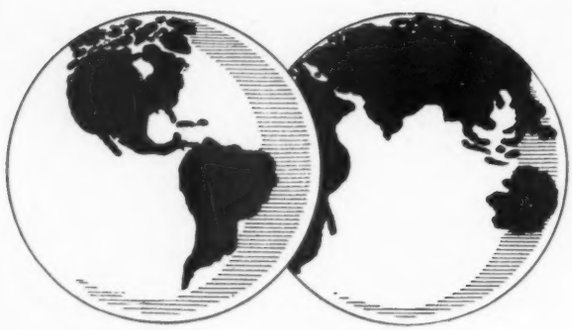
THE CAST IRON PIPE RESEARCH ASSOCIATION, THOMAS F. WOLFE, RESEARCH ENGINEER, 1015 PEOPLES GAS BUILDING, CHICAGO, ILLINOIS

SIMPLEX EQUIPMENT

for the

WORLD'S

FILTER PLANTS



From Argentina to Canada
From China to Sweden

In 39 foreign countries and in 48 states, water treatment plants equipped with SIMPLEX Venturi Type Meters, Rate Controllers, and Gauges serve more than 100,000,000 people.

Designed and constructed to meet the most rigid requirements of designing and operating engineers, SIMPLEX equipment is available for YOUR most exacting services.

LET SIMPLEX ENGINEERS AID YOU WITH YOUR METERING PROBLEMS.

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6743 UPLAND STREET • PHILADELPHIA, PA.

KY.-TENN. SECTION MEETS IN LOUISVILLE

Where 42 Years Ago Rapid Sand Filtration Won Its Spurs in Water Works Practice

By HARRY A. FABER*
Associate Editor, New York, N. Y.

Where Filtration History Was Made—The Louisville Plant (1896-1938).

FOR the 1938 meeting of the Kentucky-Tennessee Section of A.W.W.A., held at Louisville, March 21st to 23rd, balmy summer sunshine and spring flowers provided the background in contrast to the flooded river of a year ago. The Louisville Water Department, in providing a dinner and entertainment as well as a trip to the filtration plant, contributed much to the success of the busy sessions.

In 1939 the city of Memphis will be host to the section and the following incoming officers will be responsible for the program.

Officers named:

Chairman: C. M. McCord, Gen'l Supt., Water Department, Memphis.

Vice-Chairman: Hall Arnold, Water Works Engr., Madisonville, Ky.

Trustees: H. C. Bristol, Supt. Water Works, Alcoa, Tenn.

H. M. Jernigan, Wallace & Tiernan Co., Lexington, Ky.

Director, A.W.W.A.: E. E. Jacobson, Manager, Lexington Water Co., Lexington, Ky.

Secretary-Treasurer: H. G. Schmidt, State Dept. Health, Nashville, Tenn.

President Dugger's Talk Inspires

The address of E. F. Dugger, President of the National Association, proved inspirational and a stimulus to better things for A.W.W.A. and Water Works Operators. Mr. Dugger laid considerable stress on the importance of satisfactory public relations and public opinion to maintain a cooperative public attitude, and the recognition and reward which comes therewith.

To answer questions which arise, Mr. Dugger suggested the use of A.W.W.A. publications, and that the central office be called upon for aid which it is prepared and pleased to contribute.

*Research Chemist, The Chlorine Institute, Inc., New York City.

E. E. Jacobson Retiring Chairman (A. W. W. A. Directorship His Reward)

C. M. McCord The New Chairman (To sell A. W. W. A. in Ky.-Tenn.)

McCord on Membership

Noting that membership in the Kentucky-Tennessee section is sadly small for the territory it serves, C. M. McCord, the new chairman, described plans to stimulate growth. The new licensing law which will certify operators in Kentucky as well as the short schools sponsored by the Health Department in Tennessee, have contributed to greater interest of operators and should be reflected in greater section membership. The worthwhile advantages of the national association must be strengthened by active sections in the opinion of the new chairman, who stated that Kentucky and Tennessee would attempt to prove as much during the coming years.

Amongst other things, a monthly news-letter will be compiled by Secretary H. G. Schmidt, and sent to all members as a plan of familiarizing each with progress and events in the field. News items of interest from each member will be welcomed as a means of continuing active contact between meetings of the section.

On the last day of the meeting, members were taken to visit the pumping station and filtration plant of the Louisville Water Department. A demonstration of pumping equipment, of the new surface-wash system for filters, and other plant features was arranged. Many recalled that they were then standing on historic grounds. Here it was that Fuller, Weston, Ellms and their associates tested and proved the units of the new "Mechanical Type Rigid Filters" in 1895 and '96.

Technical Sessions

(E. E. Jacobson, Chairman, Presiding)

"Cleaning Water Mains," by CLINTON INGLEE, National Water Main Cleaning Co., New York, N. Y.

Three conditions which may be responsible for a reduction in water main capacity were described by Mr. Inglee as: (1) Incrustation from hard waters, which forms slowly and is difficult to remove; (2) Corrosion and tuberculation from soft acid waters, which may be responsible for great reduction in carrying capacity; (3) Organic growths and iron-bacteria in waters, which permit the development of deposits and obstruction to flow. To correct such conditions the mechanical cleaning of mains, to renew their original capacity, is warranted. Then, to maintain such recovered capacities, proper corrective treatment of the water entering the system should be instituted to check the return of tuberculation or incrustation.

Not only is the delivery of an adequate volume of water accomplished by cleaning, but savings in pumping usually pay the cost in a short time. Illustrative of this, Mr. Inglee cited the case at Salisbury, N. C., where

H. G. Schmidt, Sec'y-Treas. of Section John J. Quinn, Retiring Director of A. W. W. A., H. N. Jernigan, New Section Trustee.

reduction in pumping costs by $3.48 per M.G. followed main cleaning. Serious reductions of pressures due to tuberculation were illustrated by the case at Waco, Texas, where at 69 lbs. pressure only 550 g.p.m. could be delivered. After main cleaning the pressure was reduced to 44 lbs. and a delivery of 1,750 g.p.m. was obtained. In other instances, the increase in capacity voided the necessity of laying new mains.

At Sherburne, N. Y., pressure enhancement through main cleaning resulted in an insurance rate reduction from 43 cents to 38 cents per hundred. As an example of advantageous corrective treatment, the supply system of Utica, N. Y., was cleaned and further development of tuberculation by means of chloramine treatment had enabled a coefficient well over 130 to be maintained. (For details the reader should refer to the appended Reference & Data Section of this issue.—Ed.)

Cleaning Equipment and its use was described by Mr. Inglee who further illustrated his discussion by cost data and by slides which clearly showed the variety of pipe corrosion and accumulations which are encountered under different conditions. The discussion which followed indicated that the question of cleaner and smoother walled mains was an uppermost one in the minds of leading operators.

L. S. VANCE, Chief Engr., Louisville Water Department, told of the cleaning program in that city involving 1.5 million feet of pipe which resulted in considerable reductions in required pumping pressures. Corrosion control through lime treatment of the water had proved an effective retarding treatment, but main cleaning will probably be justified on economic grounds each 10 years.

E. E. JACOBSON, General Manager, Lexington Water Co., reported that a worthy increase of coefficients (50 to 75 before cleaning and 100 and above after) resulted from work on some 150 thousand feet of feeder and transmission mains in the Lexington system. Lime treatment is now employed, the hardness being increased about 20 p.p.m., and the coefficient of these mains is regularly checked to ascertain the effectiveness of tuberculation control.

TOM STARNES, Amer. C. I. Pipe Co., questioned Mr. Inglee on two points and was told that tuberculation will always have a tendency to proceed more rapidly after cleaning of the pipe unless corrective treatment is started. Lime treatment alone could not attack and release the run of mine type of tuberculation in cast-iron pipes.

CLARK CRAMER, Chemist, Lexington Water Co., requested H. A. Faber to give further information regarding the use of chloramine treatment for tuberculation control. Mr. Faber described the application and effectiveness of this method as experienced at Utica where biological deposition of iron has been successfully suppressed by such treatment over a period of nearly five years. (For a full report by J. Walter Ackerman, with data into 1938—see Reference & Data Section of this issue.—Ed.)

"The Graphitization of Cast Iron Pipe," by JAMES W. MOORE, Mgr. Dept. of Research, American Cast Iron Pipe Co., Birmingham, Ala.

Explaining "graphitization" as electrolysis or galvanic soil corrosion which electro-chemically dissolves out pure iron from the casting, Mr. Moore showed by photomicrographs that 7.5% to 9% of the pipe volume (2.5% to 3% by weight) is made up of graphite flakes. Cast iron pipe may have the pure iron dissolved out and the graphite matrix which remains may be sufficiently strong to resist relatively high internal or external pressures without failure.

Prof. F. J. Cheek, University of Kentucky, Louisville, Jas. M. Moore, "ACIPCO's" Research Director, Birmingham, George Tatnall, Nat'l Board Fire Underwriters, Chicago.

Cast iron differs from other ferrous metals in that the products of corrosion remain imbedded in the pipe whereas the products of corrosion of other ferrous metals are disintegrated and not thoroughly imbedded or bonded to the pipe. Studies by the U. S. Bureau of Standards were described and explained in connection with this peculiarity. When pipe coatings are used, it is of interest to note that corrosion pits frequently occur underneath the coating as well as at the bare spots. One of the most outstanding facts learned from soil corrosion tests is that, in practically every instance, the rate of corrosion decreases with time. Furthermore, a natural corrosion pit through a cast iron pipe wall leaves a matrix of graphite which prevents leakage through the pit. In any case where graphitization is severe enough to cause trouble, failure in other types of ferrous metal pipes occurs much sooner.

[Mr. Moore's very understandable and enlightening discussion has been printed in an illustrated pamphlet, and all who are interested should write American Cast Iron Pipe Co., Birmingham, Ala., for a copy.—Ed.]

H. G. SCHMIDT, Nashville, explained that the Tennessee Health Department is much interested in the problem of corrosion because some supplies of the state are

F. C. Dugan, Kentucky's Chief Health Engr., F. H. Waring, Ohio's Chief Health Engr., J. S. Watkins, Cons. Engr., Lexington, Ky.

"Tops" in Louisville's Water Works

B. E. Payne, Supt. Pumping Stations, L. S. Vance, Chief Engineer (Both Came Out of the 1937 Flood—Heroes), H. M. Gerber, President of the Water Board.

so seriously affected that many people resort to the use of springs and wells of doubtful sanitary quality. Upon questioning Mr. Moore, he was told that: graphitization does not form internally except in exceptional cases of where acid waste waters are carried; electrolytic action aggravates the condition only where the current leaves the pipe; the internal accumulation of corrosion products prevents further corrosion. If water has an ample oxygen content, the ferric oxide of rusting or tuberculation will form, but if the water lacks oxygen (such as in trade wastes or mine drainage) the ferrous iron leaves and further graphitization or pitting takes place.

"Population Forecasting," by JAMES YUNKER, Louisville Gas and Electric Co., Louisville, Ky.

In a thoughtful and well substantiated presentation of his subject, Mr. Yunker gave his listeners ample food for thought. The projection of population trends, as illustrated by birth statistics, is no longer possible and he predicted that the United States population will stop growing in about twenty years. Business and, consequently, utility expansion in the next 50 years will be entirely different than in the last 50 years.

Births began to decrease in 1922 and by 1930 it is expected that the rate will be lower than that of 1910. Population is of immediate concern to all utility officials, and the problem is by no means simple, but is complicated by many factors. For example, the contributions of science and better public health protection which tend to lengthen man's life span has some effect in counteracting declines in birth rates.*

Trends indicated by the 1920 to 1930 census show suburbs of cities increasing in population and that in the next 20 years either stagnation or a decreased rate of city growth may be expected. Technological advances are important, since a decreasing number of population can care for needs of consumers. Durable business which has a high investment (such as utilities) will suffer as a result of present trends toward dispersion of population densities and rural electrification.

While decentralization of cities means more space per person and greater lengths of main, or transmission line, per consumer, there will be a slowing of consumption per capita. Utility expansion and development will be in the details rather than in the broader aspects of development and earnings production.

F. C. DUGAN, Health Department of Ky., cited experiences in recent months with review of plans for sewage treatment plants wherein designers had been overoptimistic in the matter of future growth or expected too much of the municipal pocketbook.

"The Plant Ledger, What It Is and Why," by H. T. MATHEWS, Associated with Hendrich and Boggs, Indianapolis, Ind.

The plant ledger system Mr. Matthews described, as a method of recording capital and plant investments as well as the relation of loss in value and deficiencies in reserve accumulations. A plant ledger system for water companies provides a perpetual inventory and involves a system of work orders. Since such a system reveals a picture of all the property and equipment in service, it provides genuinely useful information and reduces speculation and argumentation as to plant and property values.

"Fire Protection," by GEORGE TATNALL, National Board of Fire Underwriters, Chicago, Ill.

In this presentation Mr. Tatnall reviewed the more important standards of the Board of Fire Underwriters and pointed out the chief deficiencies commonly detected on water system, and those which could be corrected with expense most easily justified. He pointed out the especial value of elevated storage and other items which could be set up in a betterment plan to be consummated over a period of time by systematic retirements during which community benefits could be enjoyed without waiting for funds for major operations at some future time. He felt that providing effective fire protection was as much an operating expense as a fixed investment charge against the system. It was an often told tale which justifies the retelling in many directions. Strengthening of fire protection in numerous communities is an accomplishment of which the two Federal agencies—P.W.A. and W.P.A. can well look upon with satisfaction. It was one of the most justifiable expenditures from the general funds.

"Anti-Corrosion Materials," by F. H. WARING, Chief Engineer, State Department of Health, Columbus, O.

Mr. Waring pointed out that the chemistry of what takes place in water corrosion may be complex, but the resulting effect is very easy to see. As an indication of corrosive quality, Mr. Waring referred to the modification of the "marble-test" suggested by Langelier and by DeMartini (Jan. 1938 A.W.W.A. Journal) which involves the determination of pH before and after calcium carbonate addition as a simplification in routine determinations.

This test is now made regularly by the Ohio Department on all water samples and is recommended as routine at each plant. Based on these tests, it is believed that a pH increase of only 0.2 indicates a corrosive water in Ohio. Iron content of the water (at the plant and beyond) should also be determined as an increase may be shown even where corrosion is not sufficient to produce so-called red-water troubles. Complete softening of water (especially by Zeolites) has been shown to be disadvantageous and it is now believed that the alkalinity, in the form of calcium carbonate, should be re-

Tom Starnes, Am. Cast Iron Pipe Co., Birmingham, James Yunker, Louisville Gas & Elec. Co., Louisville, Clint Inglee, Nat'l Water Main Cleaning Co., New York.

[*Recent studies made by Dr. Raymond Pearl of Johns Hopkins University show, however, that the so-called increased "average life span" is almost entirely made up of the greater saving of lives of infants and young people rather than an extension of longevity of individuals.—Ed.]

duced to no less than 40 p.p.m.—wherein, it is not necessary to add soda ash or additional lime for corrosion prevention.

The use of sodium silicate to provide a protective coating, and the recent use of sodium silicate to assist floc formation, should not be objectionable if amounts added do not increase the content beyond that of natural waters. Tests show Ohio surface waters to average 2 to 7 p.p.m. silica in solution, while that of ground waters ranges from 12 to 15 p.p.m. Apparently the amounts of silica added in treatment are reasonable and safe physiologically.

Mr. Waring warned against the use of many of the commercial corrosion inhibitors now available in industrial treatment, because frequently these contained a soluble chromate in addition to silicate. When the recommended dosage is employed, some 0.1 p.p.m. of chromium is added to the water. Since it is known that some chromium salts are definitely toxic, research as to the physiological effect of these in water supplies should be studied—meanwhile the use of this material is highly questionable in public water supply, although of reported value in industrial and re-circulatory systems.

"The Threshold Odor Test for Better Control of Tastes and Odors," by GEORGE H. HOFFMAN Industrial Chemical Sales Co., New York City.

Mr. Hoffman rather thoroughly reviewed the most successful methods of applying activated carbon, as determined by the many plants now utilizing this material.

"Regulars"

W. H. Johnson, Supt. of Water Works, Harrodsburg, Ky., Clark Cramer, Supt. of Filtration, Lexington, Ky., Earl Mitchell, Supt. of Filtration, Paducah, Ky.

amination" for prolonged antiscepsis were reviewed as suggestive of applications, realizations and limitations under actual operating conditions.

The simultaneous reactions of chlornie upon bacteria and upon "chlorine demand" materials in water was indicated as significant of water quality and reflected changing conditions as the chlorine demand varied. On this score only the residual chlorine test could be used as the proper index of chlorine sufficiency. In addition to disinfection, the value of pre-chlorination to meet other specific problems was discussed.

The chlorine-ammonia process reactions and speed

(1) *Robt. C. Terrell, City Engr., Danville, Ky.;* (2) *H. A. Perkerson, M. & H. Valve Co., Anniston, Ala.;* (3) *F. H. Stover, Asst. Engr., Louisville Water Dept.;* (4) *L. W. Thrasher, Supt. Water Works, Burkesville, Ky.;* (5) *J. F. Connerton, Asst. Engr., Louisville Water Dept.;* (6) *Frank Simmons, Supt. Water Works, Russelville, Ky.;* (7) *E. N. Shelton, Shelton Co., Chattanooga, Tenn.;* (8) *A. R. Murphy, Division Manager, Wallace & Tiernan Co.*

A continuous dose of carbon applied to the raw water, with thorough mixing, was recommended to produce water of better quality as well as a scheme of coping with sudden and unexpected taste and odor flares.

The practical test to determine the dose of activated carbon required to remove tastes and odors from raw water, which was demonstrated, involves the use of simple, easily obtainable equipment, and may be carried out with little preparation.

A more refined test was suggested where more elaborate laboratory equipment can be provided. (Too extensive for reporting here, directions for carrying out both tests are being distributed gratis by Industrial Chemical Sales Company as a means of suggesting a system of carbon dosage control which will meet the requirements of the condition but, likewise, prevent waste of carbon.—Ed.)

"Modern Chlorination," by HARRY A. FABER, Research Chemist, The Chlorine Institute, Inc., New York City.

Because of the widespread adoption of chlorination for one or another purpose and the extending use of the chlorine-ammonia process, Mr. Faber felt that some discussion of the basic principles involved should prove helpful to those using these methods.

Fundamentals in the chemistry and biological effects in oxidative direct chlorination and restricted "chlor-

of bacterial kill were shown to be intimately connected with the hydrogen ion concentration of the supply, and water temperature in particular. In general the speed of kill dropped with water temperature drop, or with increase in pH value. In particular, however, the effect of chloramination on the distribution system affords marked advantages, since a residual may be carried throughout the system with several resulting benefits. Taste and odor control measures, made possible with this and by combination processes, were described. Chlorination of mains was touched upon by Mr. Faber who cited the procedures recommended in the A.W.W.A. "Report on Laying C. I. Pipe" which had won for the chairman of the committee the John Diven medal.

H. G. SCHMIDT (Tennessee Health Dept.) stressed the desirability of more frequent chlorine demand determinations to insure an effective chlorine residual under *all* circumstances. Infrequent tests for residual had proved inadequate protection—especially in connection with unfiltered supplies.

Memphis—1939

The new chairman, C. M. McCord, said that he had come to Louisville with every intention of taking the 1939 meeting back with him to Memphis. His "intentions" were apparently strong enough—for it's Memphis in 1939 for the Ky.Tenn. Section.

DENVER — a typical example!

Ease and speed of installation by unskilled labor was the conspicuous feature of Dresser-coupled conduit No. 17, between filter plant and city . . . *Consulting Engineer:* Herbert S. Crocker, Denver, Colo. *Contractor:* Williams Bros. Corp, Tulsa, Okla.

OTHER CITIES JOIN IN!

Dresser Couplings are winning wider approval all the time. Take cities like:

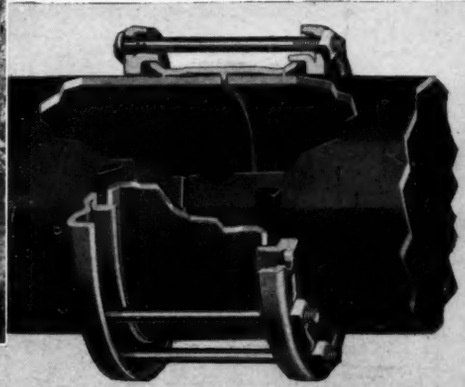
Columbus, O. — Kansas City, Kans.
Covington, Ky. — Lynchburg, Va.
Ft. Smith, Ark. — Salt Lake City, Utah

Dresser Couplings have again won the enthusiastic approval of those in charge of pipe-line construction—this time in connection with Denver's new water-conduit work. Sizes of the steel pipe range from 63″ on down through 57″, 51″, 36¾″, to 30¾″ O.D.—and on all of it Dresser Couplings were used!

FIVE REASONS WHY MODERN WATER LINES ARE DRESSER-COUPLED:

1. PERMANENT TIGHTNESS—proved for 50 years, on 150,000 miles of pipe.
2. FLEXIBILITY—normal pipe movements—present in every line—are absorbed.
3. SIMPLICITY—joints are "factory-made"; ordinary labor can install.
4. STRENGTH—predetermined; joints safely withstand any specified pressure.
5. TRUE ECONOMY—a truly lower joint cost throughout the life of the line.

Write for our General Catalog No. 36.



Cutaway view of Dresser Coupling, Style 38, showing working principle. Note that plain-end pipe is used. The *resilient* gaskets, flexing with the pipe, safely absorb pipe movements.

THE MODERN TREND IS TO DRESSER COUPLINGS

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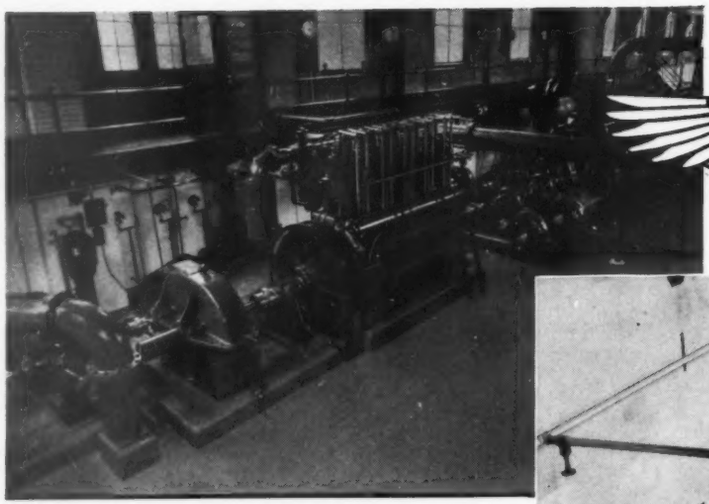

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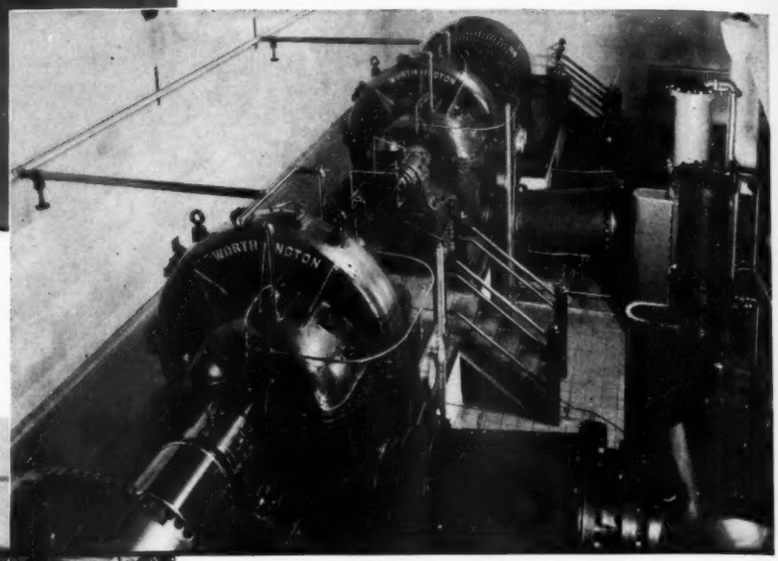
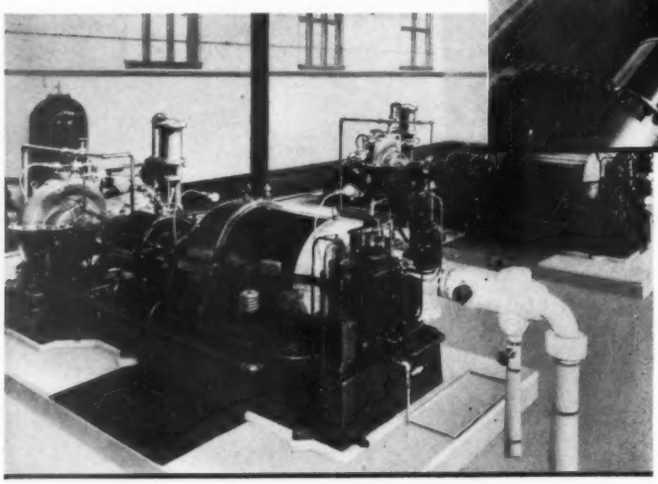
One 8-MGD and one 4-MGD Unit. Worthington 450- and 300-hp. Engines



MOTOR DRIVEN UNITS
Two 40-MGD Units. 1200-hp. General Electric Motors



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MAINTENANCE OF ELECTRICAL EQUIPMENT IN WATER AND SEWAGE PLANTS

By S. A. CANARIIS

Water Works Engineer,
Westinghouse Electric & Mfg. Company,
East Pittsburgh, Pa.

*The Author**

AN ERRONEOUS assumption that electrical equipment will give the most satisfactory service by "leaving well enough alone" is found to be a rather common belief. Too frequently is this true where electrical equipment is employed in automatic operation. This is unfortunate, since a failure in a small part in such stations may cause serious damage in major electrical or hydraulic equipment and an equally serious disruption of service.

Satisfactory operation of electrical equipment is primarily dependent on maintenance of insulation, because breakdowns in insulation usually occur without warning, or without indication of weakened resistance. While many other parts of electrical equipment, whether it be bearings, commutators, instruments, breakers, etc., require regular maintenance, they can usually remain in service until a shut-down for this purpose can be arranged without interfering with the service.

**From 1930 to 1937, the author was electrical engineer for the Bureau of Waters, City of Pittsburgh, responsible for design, construction and maintenance of all electrical equipment and installations. Ranging from fractional horsepower to 2250 Hp. motors, this bureau's motors total approximately 20,000 Hp. During the 1936 flood, Mr. Canariis was in direct charge of the reconditioning and restoration to service of the electrical equipment in the flooded plants. His record from that service alone qualifies him to speak with authority on the subject of maintenance.*—ED.

Inspection Records and Schedule

One of the first requirements in maintenance work is systematic inspection and recording of all equipment. One of our leading cities has successfully employed the illustrated forms of records for rotating and control equipment. These forms, of which one is kept for each piece of equipment (numbered in identifying groups for each station) carry a complete record of installation and maintenance. This enables the superintendent to requisition spare parts or replacements without delay, and provides a definite check on the frequency of inspection and efficiency of the maintenance force. The form sheets are bound in one book for each station, and the Chief Station Engineer is responsible for having all test and maintenance work properly entered; the books are forwarded to the Superintendent once each year for checking against the inspection schedule.

Inspection and maintenance schedules must be prepared on the basis of local installations and operating

BUREAU OF WATER - MECHANICAL DIVISION — OIL CIRCUIT BREAKER RECORD

O. C. B. NO. | STATION | APPLICATION
POLE— THROW | MAKE | TYPE
AMPS. | VOLTS | RATED INTERRUPTING CAP= KVA
GAL'S. OF OIL
CLOSING MECH. : MANUAL - SOLENOID : PULL-IN= A. AT V. : HOLDING= A. AT V.
TRIP MECH. : MANUAL - C. T. DIRECT - SOLENOID : PULL-IN= A. AT V.
REMARKS:

OPERATING RECORD — DATE INSTALLED

INSPECTIONS AND TESTS					REPAIRS AND REMARKS
DATE	CONDITION	CYCLE COUNTER	OIL INS. RES.	INSP. BY	

Oil Circuit Breaker Record Form.

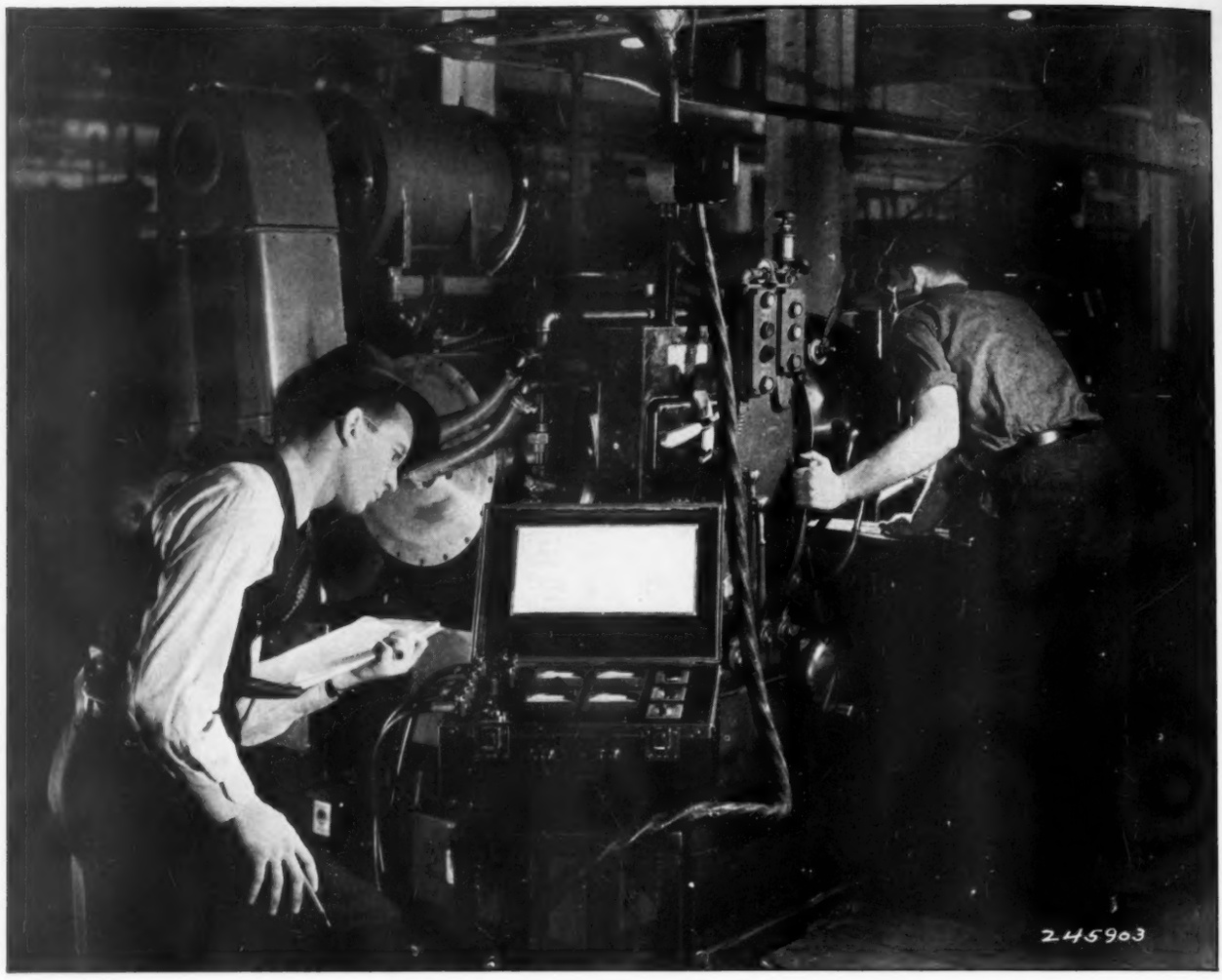
BUREAU OF WATER - MECHANICAL DIVISION — ELECTRIC MOTOR RECORD

MOTOR / GENERATOR NO. | STATION | APPLICATION
RATED H. P. / K. W. | SPEED SYN. R. P. M. / F. L. R. P. M. | VOLTAGE RATED AT VOLTS / CONNECTED FOR VOLTS
PHASES CYCLES | F. L. AMP. | NO. OF POLES
MAKE | TYPE | SERIAL NO.
FRAME | TEMP. RISE °C | EXC. FOR 1.0 P. F. A. AT V.
BRUSHES: TOTAL NO. | SIZE | STOCK ITEM NO.
COUPLING OR PULLEY
REMARKS:

OPERATING RECORD — DATE INSTALLED

INSPECTIONS AND TESTS					REPAIRS AND REMARKS
DATE	CONDITION	INSULATION RESISTANCE		INSP. BY	

Electric Motor Record Form.



Checking Electrical Load Characteristics of a Motor. Note Portable Analyzer Used.

conditions. For example, more frequent attention must be given to equipment which is installed in exposed locations or subjected to severely fluctuating operations, than to equipment which is operating under protected or ideal conditions.

Testing

The most important piece of equipment used in testing for maintenance of electrical equipment is probably the "megger" or an ohmmeter, by which the insulation resistance may be ascertained by direct readings. In general, a minimum insulation resistance between conductor and ground of 1000 times working voltage, expressed in ohms, should be maintained. An exception to this rule is the field in A.C. rotating machine which, on account of the high voltage induced in the closed field during starting, requires an insulation resistance of one-half to one megohm.

It is equally necessary to have facilities for testing for causes which may result in apparatus failure. Such for instance as high or low voltage, or unbalanced voltage in polyphase systems. Convenient test kits are commercially available, at reasonable costs, which enable the inspector to make a complete motor or circuit analysis through one single process of connection. Even more convenient is the modern method of installing a permanent instrument or meter socket in the lead to each apparatus, so that the circuit can be tested with individual instruments without the necessity for any field connections or test leads.

Temperatures—Insulation and Bearings

High operating temperatures will materially shorten the life of any insulation. Unless specially designed for high temperature operation, no apparatus should be allowed to operate at a total temperature of more than 90° C., as measured by a thermometer. This allows for a variation of 15° C. between the "observed temperature" and the temperature of the "hottest spot" in the windings. While this total "observable" temperature is the maximum allowed for "Class A" insulation, the "Class B" insulation permits operation with a maximum observable temperature of 110° C., and "Class O" insulation is limited to 75° C. for safety.

The temperature rise of bearings should not exceed 45° C. for friction type bearings and 15° C. for anti-friction type bearings.

The ratings of equipment are based on an ambient temperature of 40° C.; when the ambient temperature is lower than 40° C., the permissible temperature rise is increased correspondingly.

Care of Insulation

When a new motor or other wound coil apparatus leaves the manufacturer's plant it is assumed to be in perfect condition. During shipment, or after its installation, it may collect a sufficient amount of condensation to lower the insulation resistance below a safe level. Before placing new equipment in operation it should, therefore, be tested for dryness of insulation, and for safety

should be properly dried out before operating. In many cases, this initial drying out may be accomplished by operating the motor at a low voltage and at no load until the resistance has been restored.

Clean insulation is essential for long life. Any accumulation of dirt, water, chemical compounds, oil, etc., may cause a rapid deterioration of the insulation materials. Protection of the surface, which in most cases is the insulating varnish applied to the finished coil, will prevent most insulation failures. During operation of the apparatus, the electrical stresses will tend to force the coils out of shape; this, together with continuous temperature changes, will result in a cracking of even the most flexible insulating varnishes, thus admitting moisture to attack the insulation on the windings.

For these reasons, all motors should receive a regular cleaning and re-varnishing. Blowing out by dry compressed air at about 50 lbs. pressure is effective for removal of dirt which can not be reached with a cloth. However, care should be used not to apply too strong air pressure, as this may loosen the bindings and lodge the dirt underneath the coils. Compressed air simply changes the location of the dirt, and is therefore not recommended for a cleaning job in the operating room. Removal of dust may be accomplished by using a clean, lint-free cloth. Never use waste for this operation, because the lint will stick to the insulation and later pick up moisture and oil.

Where oil and grease is present, it may be necessary to apply a solvent, either the commercial standards such as "Cleaner's Naphtha," "Stoddard Solvent," etc., or a mixture of 50% carbon tetrachloride and 50% benzine or gasoline. When using these solvents it is necessary to provide adequate ventilation, preferably exhaust, to avoid the toxic or explosive effects of the gases.

After cleaning, the coils should be thoroughly dried until the new insulation resistance has been restored. Drying may be accomplished by applying external or internal heat, or a combination of both. External heating may be by means of low pressure steam coils or radiators placed below the windings, by blowing hot air from electric heaters or unit heaters through the apparatus, by placing electric space heaters under the end windings, or by any similar source of heat; an enclosure of the frame will concentrate the treatment, and a ventilating opening in the top of this enclosure will produce a draft and provide an escape for the moisture. The heat should be brought up slowly to give a maximum coil temperature of 85° C., and maintained until the insulation resistance has dropped to a minimum and then increased to a satisfactory value, after which the heat should be removed gradually.

Internal heat may be applied by circulating a low voltage current through the windings. If the insulation contains an appreciable amount of moisture, a too rapid application of this type may cause generation of vapor or gases within the coils, and at such high pressures that the layers of insulation may be ruptured. If alternating current is applied to the stator windings it is necessary to short-circuit the field windings to avoid dangerously high induced voltages.

Value of Drying Oven

One of the best investments in maintenance equipment is a permanent drying oven, which may be constructed cheaply from brick, concrete, or steel, with inside insulation. A suitable and easily controlled heat source such as steam radiators or electric space heaters should be installed in the bottom of the oven, and controllable ventilation openings provided both at bottom and top of the oven. A remote indicating thermometer is useful for showing the oven temperature, and it may even be arranged for the safer automatic control of the heaters. This same oven will also be found extremely useful for baking of the coils after application of insulating varnishes.

Measuring Electrical Loads With Socket Instrument Receptacle and Socket Type Ammeter Above.

After drying, and an oven pre-heating of 85 to 100° C., the apparatus coils must be given a thorough application of a recommended grade of baking varnish, preferably applied by dipping. If necessary, it may be applied by brushing or spraying, but this method is not always as certain to fill all cracks and crevices as the dipping. This varnish application should be baked at a temperature as recommended by the varnish manufacturer, and for periods of from six to forty-eight hours, depending on the size of the apparatus. After one or several coatings and bakings, the coil may be given a spray-coat of air-drying varnish, which produces a smooth coating of high dielectric strength. Coils should be kept on end during varnishing and baking to avoid an unbalanced condition from the piling up of varnish on one side.

Coil Bands

Coil bands must be inspected for looseness, and if necessary replaced with new bands of the same dimensions. Use of wider metallic bands may cause heavy current in the bands, sufficient to overheat and melt the solder.

Commutators

Application of heat during drying and baking may warp the shape of the commutator, and it should be trued and polished in a lathe as a final operation. Before truing, it must be examined for looseness, by light tapping with a small hammer on the bars; if the commutator does not ring, but sounds flat when struck, the front "V" ring must be tightened.

This front "V" ring of a commutator is especially susceptible to attacks from moisture, oil and dirt, and it should, therefore, be thoroughly cleaned and given a protective wrapping of twine and surgical tape, and finished with one or several coats of special oil- and moisture-resisting cement.

Moisture or water which has penetrated the "V" ring may usually be removed by unscrewing two diametrically opposite fastening studs or bolts, and passing hot air through the inside of the commutator. If this method is not sufficient, the "V" ring must be loosened or removed after the commutator bars have been securely banded.

Brushes

Brushes must be accurately adjusted and fitted, both for free movement without "cramping" in the brush-holders, and for contact with the commutator or collector rings. Spring tension must be checked, as must the alignment of the brushes; these must be staggered for alternate polarity. Special care must be taken in keeping the commutator surface and slots clean, and to remove dirt and carbon particles which may have become lodged between the brush and commutator.

Bearings

The proper maintenance of bearings is familiar to all operating engineers, and is mentioned here only to call attention to its connection with the electrical performance. When bearings are adjusted, it is essential to make an accurate check of the air gaps of the machine, so as to insure a centering of the rotating element. Bearings may become overheated from excessive side pull, caused by the rotor being out of center, or from an end thrust created by a magnetic pull on the rotating part.

Oil Circuit Breakers

The three main points of inspection of an oil circuit breaker are the condition of the oil, contacts, and operating mechanism.

The conventional type of oil circuit breaker must be inspected after each severe fault-operation. This, in addition to the regular inspection each year or for each 150 to 250 normal operations. New insulating oil should test approximately 29 K.V., and old oil should be replaced when a sample test shows a flashover value of less than 18 K.V. When replacing oil, the inside of the breaker tank must be carefully cleaned and wiped with lint-free absorbing paper, manufactured for this special purpose. New insulating oil, which has been stored for even a short length of time, may have absorbed a sufficient amount of condensation moisture by "breathing," and must therefore be tested before using; a water-seal on the drum is usually effective in reducing this "breathing" effect.

Contacts, both main and auxiliary, should be filed and polished, if necessary, and adjusted for a uniform "wiping" contact and simultaneous contacts for all poles.

The operating mechanism should be lubricated to operate freely, yet positive in all positions. Make sure that all nuts, bolts and set screws are tight, and that all cotters are in place.

Bushings must be cleaned, and inspected for possible cracks and other faults. Tank bolts should be tightened up to give a uniform pressure on all points of the gasket.

Dashpots, which are often used for time delay features in oil circuit breaker operation, must be drained and washed with a solvent, to remove all gummy and sticky deposits. Refill with fresh dashpot oil to the indicated level, and make sure that the plunger arm operates freely in its guide.

Contactors

Air break contactors, when not provided with the modern arc quenching devices, require most frequent inspection and maintenance. The contact surfaces must be filed to a smooth, parallel, and uniform contact. The springs should be checked by means of an ordinary spring-scale, and adjusted in accordance with the manufacturer's original recommendations. The operating solenoid armature surfaces must be kept clean and adjusted for uniform contact, in order to avoid excessive heating of the solenoid; the air gap must also be checked if the operating pull-in current appears excessive.

A Few "Don'ts"

Many a good maintenance or repair job has been ruined by careless handling. This is a warning against some of the most common errors:

Don't place or roll an insulated coil or armature on the floor.

Don't allow an armature to rest on its commutator or coils.

Don't lift an armature except by its shaft, or if necessary in a wide lifting belt.

Don't use a spray either for cleaning or varnish without grounding the nozzle.

Don't use solvents without having fire extinguisher ready for use.

Don't fail to refer to the manufacturer's instruction books on adjustments and maintenance of electrical equipment.

And, last—but not least:

DON'T FORGET, that any reputable manufacturer of electrical equipment is just as interested in having their products properly maintained as is the plant engineer or superintendent. The services of their engineering and service departments are always available for consultation and advice on maintenance problems.

▼

WEST VA. CONFERENCE VOTES TO AFFILIATE WITH A.W.W.A.

A report has been received to the effect that a count of mailed ballots, returned by 250 members of the West Va. Conference of Water Works Operators, revealed a 100 per cent vote favoring the establishment of a West Va. Section of A.W.W.A.

The formal application to A.W.W.A. for the creation of a West Va. Section will hinge now on an application presented by existing members of the Association who reside in West Virginia, and at present members of the Central States Section (Ohio, W. Va., Michigan and Western Pennsylvania). It is proposed by the investigating and petitioning committee, of which A. R. Todd of Wheeling, W. Va., is the chairman, to get the petition in readiness for presenting to A.W.W.A.'s Board of Direction during the New Orleans Convention late this month.

▼

BIDS ASKED FOR SHASTA DAM—The U. S. Department of Interior will open bids June 1 for constructing Shasta Dam and Power Plant. The work calls for 5,610,000 cu. yds. concrete.

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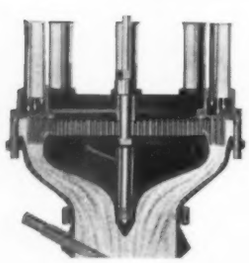
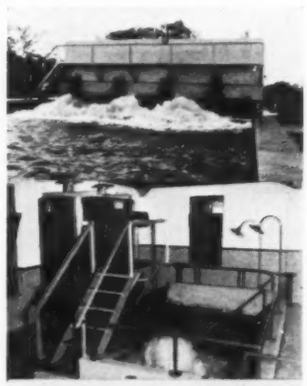
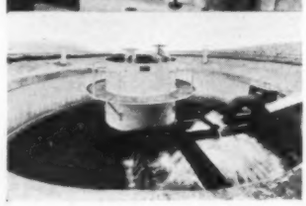


Cross section of Aer-O-Mix aspirator tube head and throat.

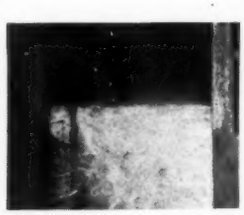
For outside or inside installation. Non - freezing. Gravity (head loss) type; Rotary (motor-driven — no head loss) type; Pressure type; Self-contained, closed unit type. For use in water treatment plants; sewage treatment plants; industrial waste treament, etc. A six-point method involving diffusion, compression, retention, expulsion, surface contact, agglomeration.

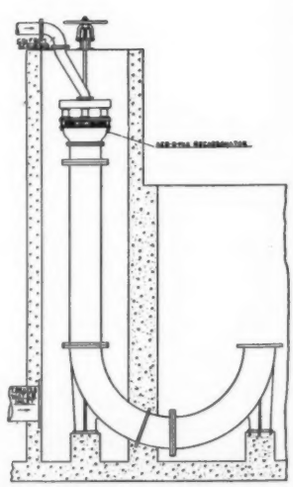
"Jung Suction" AER·O·MIX AERATOR - MIXER





Pictured at right are photographs of (1) Rotary Aer-O-Mix with submerged discharge; (2) looking down on surface of carbonation chamber with submerged discharge Aer-O-Mix carbonator. Below, sketch showing Rotary Aer-O-Mix carbonator for drawing gas direct from scrubber and effecting complete diffusion. At left, views of inside and outside gravity Aer-O-Mix installations.





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LIMESTONE CONTACT BEDS FOR CORROSION CONTROL

Results of Full-Scale Operation

By I. M. GLACE

Consulting Engineer
Harrisburg, Pa.

The Author

IN A PREVIOUS article, which appeared in the January, 1937, issue of WATER WORKS AND SEWERAGE, the author described the experimental plant of the Dillsburg Water Co. (Dillsburg, Pa.), and summarized the data which led to the installation of a full-scale plant for the correction of corrosion, using for treatment of the water limestone contact beds. The full-scale plant was completed and placed in operation in May, 1937, and has been in continuous operation since that time.

The Dillsburg Water Company takes water from a dozen springs located in the sandstone hills to the west of Dillsburg, and serves that borough and adjacent territory. The average daily consumption is estimated at about 40,000 gallons. The water is used without treatment—except as here described—and is collected and distributed by gravity. Originally the distributing and storage reservoir floated on the gravity supply line to the distributing system. Now, under the new method of operation, all of the water must enter the reservoir after passing through contact beds, consisting of crushed limestone rock. Excess water is wasted through the overflow of this basin, which has a capacity of about 450,000 gallons.

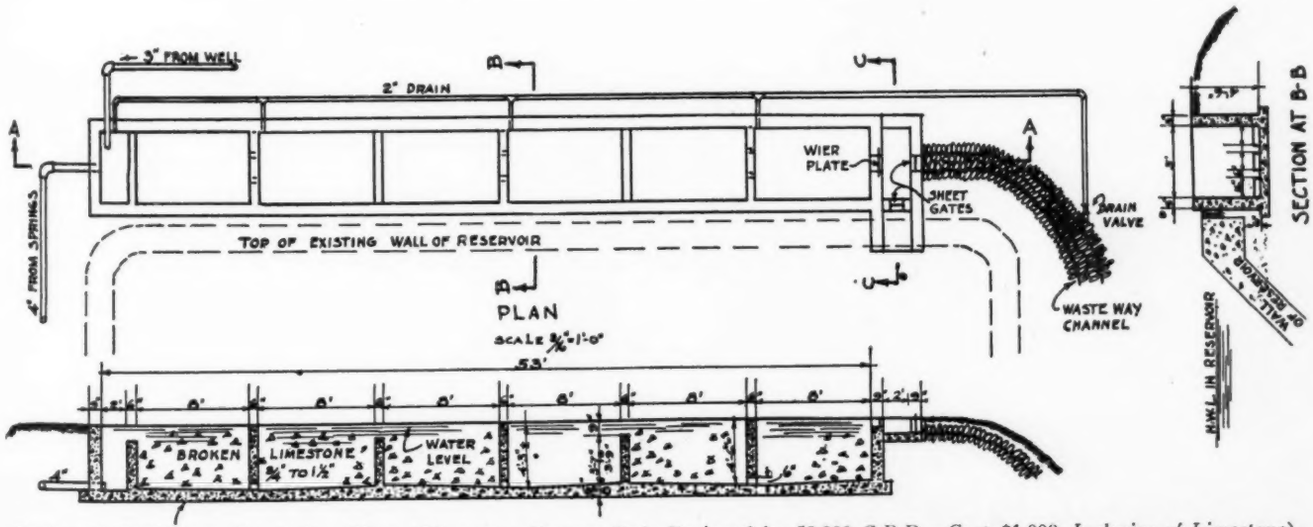
The Contact Bed

The limestone contact bed consists of a concrete basin with inside dimensions, 55 by 5 ft. in plan, and 4 ft. deep. It has inlet and outlet chambers and a flowing through compartment, divided into three sections by concrete over and under baffles to induce up and down flow through the crushed limestone. Blowoff lines are also provided for draining and cleaning. A weir at the outlet end is provided for the measurement of the treated water. It is also possible to bypass the entire treatment works and storage reservoir through the gravity main to the system. The tank was waterproofed with "Bitumastic" enamel supplied and placed by the Wailes-Dove Hermiston Co.

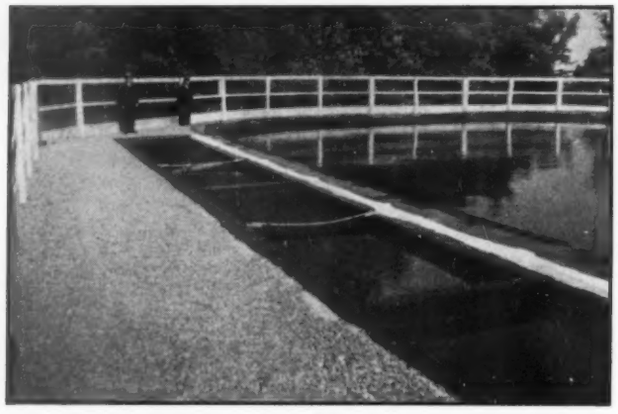
The flowing through compartments of the contact bed are filled with crushed limestone, screened to ¾ to 1½ inch size. This material was taken from the stock pile of a local quarry and was originally prepared as aggregate for road work. The broken stone was first washed before placing and finally thoroughly disinfected, in place, by the repeated application of hypochlorite of lime solutions.

Results of Operation

The data secured on the operation of the full-scale plant confirm the data secured from the experimental installation described in the earlier article. The findings also confirm those of Cox[1] and Ryon,[2] who appear to be the only other persons in this country to have published information on this form of corrosion control. The pH, alkalinity, and hardness of the treated water seem to have increased to about the anticipated extent, with corresponding decreases in the carbon dioxide content.



Design of Dillsburg's Hardening Plant (Limestone Contact Beds Designed for 50,000 G.P.D.—Cost, $1,000, Inclusive of Limestone).



Limestone Contact Beds, and Dillsburg's Reservoir on Right.

Curves, in which the pH is plotted against contact time, follow approximately the same line, and show a rapid pH increase during first hour of contact, followed by a flattening of the curve on longer retention. However, there is a constant gain within the time limits recorded up to 3½ hours of contact.

Average figures on raw and treated water are here tabulated:

	Raw Water	Treated Water*
pH	5.4	7.3
Alkalinity	12 p.p.m.	44 p.p.m.
Hardness	8 p.p.m.	40 p.p.m.
Carbon dioxide	20 p.p.m.	5 p.p.m.

*Based on a contact period of approximately 2½ hours.

The actual contact period at Dillsburg on full scale has been quite constant over most of the past season, since just enough water has been run through the plant to maintain the distributing reservoir at or near its maximum level, variations in daily and hourly consumption being taken care of with the water in storage, which is ample for this purpose without serious depletion at any time. Small amounts of treated water have gone to waste, through the reservoir overflow, at nights and on Sundays when the draft has been at a minimum. The calculated period of contact has been close to three hours, based on the assumption that the voids in the stone amount to 50% of the bed volume.

Routine checks in plant operation have been confined mostly to colorimetric pH determinations, rather than by CO_2 tests and other analyses. This has been the case because of the ease and simplicity of the pH test; although it is believed, as judged by more complete data, that this determination alone provides sufficient information to determine efficiencies on a practical operating scale. A series of such tests, typical of many others, is tabulated at this point and will later be discussed.

pH DETERMINATIONS
(Full-Scale Plant)

Inlet	First Baffle	Second Baffle	Outlet	Reservoir Overflow	Consumer's Taps
5.4	6.8	7.1	7.2*	7.5	7.6

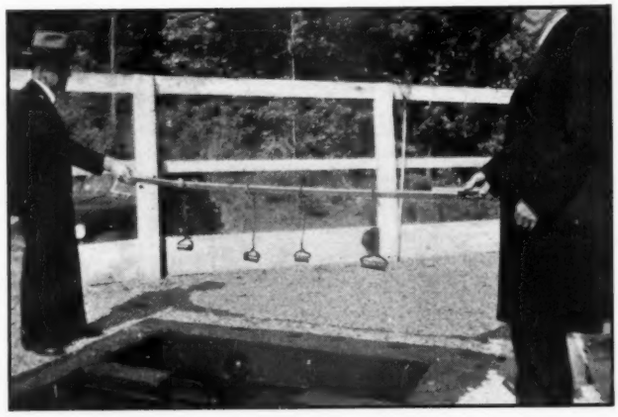
*After about 2.5 hours contact in flowing through the bed.

From the consumers' standpoint, as well as that of the water company, the treatment has been a success. Iron and other metallic tastes have disappeared at the taps, and complaints of stained laundry, formerly frequent, are no longer received. Even water stored in flasks in refrigerators has failed to show the characteristic stains common to water carrying iron in solution. The water company has noted, also, a marked reduction in the number of service meters which must be cleaned and replaced.

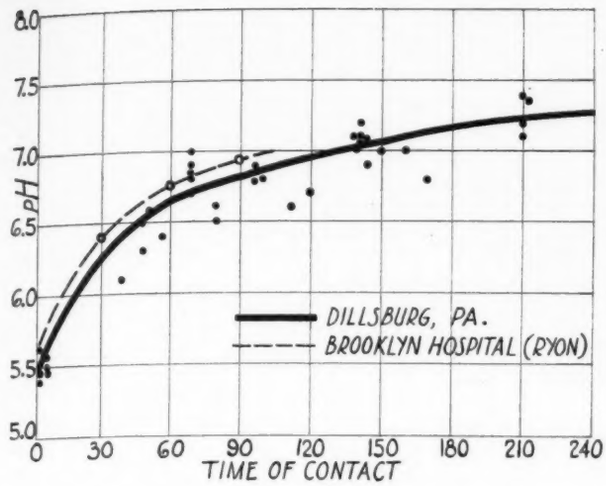
The only drawback to the treatment has been the increased hardness, which has been commented on by certain of the consumers. This of course was anticipated, particularly in view of the extremely low hardness of the spring supply which has never been found to contain as much as one grain per gallon of total hardness. The maximum at the taps in Dillsburg during the past season has been about three grains (50 p.p.m.), which would be considered to be a reasonably soft water by the average water user.

As shown by the accompanying photographs, the contact beds are uncovered. Because of the high CO_2 content of the raw water, some algae growths have occurred, as anticipated. These, however, have not interfered with the operation of the plant. Long thread-like filaments have formed, especially at the inlet end. The growth has been identified as Mougeotia, an inoffensive organism belonging to the same group as does Spirogyra, a common and better known form. These growths have been controlled through the application of copper sulphate at the inlet end. If they should become of moment at any time they can be eliminated, of course, by covering the structure to exclude sunlight. No growths of any kind have been noted in the storage reservoir. Covering was not included in the original design because of the lack of cover over the storage reservoir and the isolation of the structures.

Maintenance costs up to this time have been negligible and apparently will continue to be so for an indefinite time. Only in the down-flow side of the first compartment has there been any measurable reduction in the level of the stone in the bed, or in the size of the stone, due to the dissolving action of the water. In this portion of the bed (one-sixth of the total area) the loss has been, however, about 4 inches in a total of 4 ft. The size of the stone particles in this portion of the bed is likewise noticeably less, although no actual screen test has been made to determine to what extent. Based on admittedly approximate computations and reduced volume of limestone (not all of which is available as calcium carbonate), the rate of solution seems to be about 200 pounds for each million gallons of water treated. This figure is approximately 1 grain per gallon, which compares, to some degree, with the dosages used by other installations where slaked or hydrated lime is used for corrective treatment. On the basis of the original cost of the broken limestone, the cost of the "chemical," if it may be so called, has been about 15 cents per million gallons.



One Set of Test Specimens of Service Pipe. This Set Is Suspended in the Effluent; Others at the Inlet End and at Intermediate Points



Graph Picturing Relationship of Contact Period to pH Increase (Limestone Contact Beds).

Effectiveness

In an attempt to show the efficiency of the treatment, sections of service pipes have been suspended in the water at the inlet and outlet ends of the contact bed, and at two intermediate points, as shown by the accompanying photographs. Heavily insulated wire has been used for the hangers, to eliminate possibilities of galvanic action between the metals. These sections of pipe (left to right) consist of galvanized iron, wrought iron, brass, and copper. It is somewhat early to comment on the action occurring, because up to this time only the galvanized iron at the inlet end has shown any noticeable deterioration.

An unexpected result of the treatment at Dillsburg has been the markedly improved appearance of the water in the distributing reservoir. This water formerly was considered to be quite clear and had no apparent turbidity. Now, however, it has an extreme clarity and sparkle and a particularly inviting appearance. The reasons for this improvement are not entirely clear. It is possible that the contact beds, filled as they are with coarse material, have served to remove certain colloidal materials from the water. It is also likely that the iron formerly picked up from the pipe system and service lines may have been responsible for a slight color and murkiness.

Costs

The total cost of the completed project, including piping changes, was about $1,000 for the plant capable of treating 50,000 gals. per day and upward. The 40 tons of stone used (included in the $1,000), were bought at $1.65 a ton, delivered at the plant. The cost of treatment (limestone dissolved) has been estimated at 15 cents per million gallons.

Discussion

The author desires to emphasize, as he did in his former article, that the process seems to be applicable only to those communities having a low average consumption but that, on the other hand, there are many scores of such supplies in eastern United States which have as sources springs, spring-fed streams, and wells in sandstone formations and, consequently, serious corrosion problems; and that to these communities the cost of standard forms of treatment would be unduly excessive from an operating standpoint. The economical maximum quantity of water to be treated by contact beds would seem to be in the neighborhood of 500,000 gallons a day, although of course many variables must be considered before a proper determination could be made. Some of these variables would include the character of the water (and more particularly its CO_2 content and carbonate hardness), the physical characteristics of the supply and the accessibility of the proper place for treatment, the head available for aeration, maintenance costs, and similar factors which enter into any well-considered engineering project. The process certainly would seem to be applicable for the treatment of water of institutions, estates, and individual homes in rural areas.

This method of control is not new. Cox, in his article in 1933[1], mentions three foreign installations, particularly one at Frankfurt, Germany, where a plant has been in operation since 1908, treating from 8 to 11 million gallons a day with crushed marble, which is dissolved at a rate of about 600 pounds per million gallons treated. Cox further lists some half dozen experimental and full-scale plants treating small quantities of water, all in New York State. Ryon, in his article of 1935[2], describes the plant installed at the Creedmor Division of the Brooklyn State Hospital, treating better than a half million gallons a day.

The author, in addition to the experimental and plant scale experiments at Dillsburg, has made studies of the process at other places, and has recently prepared tentative plans for a second water company installation for the treatment of a daily consumption of 150,000 gallons.

The data thus collected from these several sources are sufficiently authentic and confirmed to warrant acceptance of the process amongst other methods for the control of corrosion, when such corrosion is due to an excess of carbon dioxide or deficiency in hardness. With sufficient contact time, aggressive carbon dioxide can be removed from normal supplies, the speed of the reaction being influenced largely by the initial CO_2 content and other factors. With normal temperatures, low alkalinities, and high CO_2, a large part of the effect is found to occur in the first half hour, after which, as the alkalinity and hardness increase, the reactions become very much slower. The pH-time curve of the full-scale plant in Dillsburg follows very closely that of the similar installation of the Brooklyn State Hospital, despite the probable superiority from a chemical standpoint of the marble used at the hospital as compared with the less expensive limestone at Dillsburg. This naturally brings up the question as to whether or not, economically, or as regards efficiency, there is anything to be gained through the use of a material with a high calcium carbonate content, except possibly for the capacity of the contact chamber.

One of the interesting points noted in the Dillsburg results is the persistent increase in the pH of the treated water in the storage reservoir after the treated water is discharged from the contact bed, followed by a very slight increase in the distribution system. The increase in the reservoir may be due to a further loss of CO_2 in the basin, although the author is disinclined to accept such a theory, which would hardly apply to the action in the piping system. It seems more probable that ionization continues after contact of the water with the stone has been completed, with a further reduction in the number of hydrogen ions, and an increase in the pH scale. This phase of the reactions has attracted attention only recently, with the accumulation of operating data, and needs further investigation, as does also the possibility of a corresponding increase in the hardness and alkalinity at the same point.

This continued maintenance of the pH throughout the distribution system is of particular interest to the author, since it seems to be at variance with results noted elsewhere, not only by the author but other observers as well. In a number of cases where treatment with lime is practiced there is a measurable drop (sometimes very pronounced) in the pH of the water between the point at which the water enters the distribution system and where the water is taken from taps. Such decrease seems to be progressively greater as the water moves to the far ends of the piping system. Even in two of the larger eastern cities where lime has been applied for a number of years as a corrective, such a drop, although slight, is said to occur. Similar data on alkalinities, which may be of greater importance than hydrogen ion determinations, are not available, although the alkalinity is not greatly affected.

Whether this deviation from the normal (if such it is) is due at Dillsburg to the unusual type of treatment, or to other phenomenon, requires further study. At Dillsburg the entire piping system was scraped and cleaned some six months before corrective treatment was instituted; whereas, so far as is known, at all other places under observation, the original tuberculations were still in the pipes when treatment was started. This matter of drop in pH was discussed at the Four States Meeting of the American Water Works Association in 1937, but without reaching a definite conclusion.

Baylis, in a recent article on corrosion[3] points out the difficulty of determining calcium carbonate equilibrium by means of the equilibrium curve, and stresses again the desirability of the "marble" test. This test has not been made recently on the Dillsburg water, but it is doubtful that the water of Dillsburg, or elsewhere, can be carried to this desirable maximum by means of the limestone process and a reasonable period of contact. In many cases, seemingly, natural limestone waters have been used for years without appreciable deterioration of the mains and service lines, although such waters are apparently not in real equilibrium. Considerable study still is needed before the problem of corrosion is fully understood and placed under absolute control, but the limestone contact scheme seems to have merits not to be lost sight of.

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1. Cox C. R. The Removal of Aggressive Carbon Dioxide by Contact Beds of Limestone or Marble. J., A. W. W. A. Vol. 25, No. 11 (1933).
2. Ryon, Henry. Corrosion Control with a Marble Filter. W. W. & S., Vol. 82, No. 10 (Oct., 1935).
3. Baylis, John R. Treatment of Water to Prevent Corrosion. J., A. W. W. A., Vol. 27, No. 2 (1935).
4. Glace, I. M. Limestone Contact Beds for Corrosion Control. W. W. & S., Vol. 84, No. 1 (January, 1937).

ARKANSANS HOLD THEIR MOST SUCCESSFUL CONFERENCE

The 8th Annual Arkansas Water and Sewage Conference held at the University of Arkansas, Fayetteville, March 28-29-30, aside from establishing a record attendance, proved to be the most enthusiastic meeting yet held. Approximately thirty per cent more towns and cities were represented than in any other year.

The following papers were presented:

"Relations Between Fire Protection and Service Requirements" by H. T. Buchanan (L. A. Jackson discussor).

"Electrolysis of Water Mains" by R. J. Rhinehart (H. S. Peck, discussor).

"Valve and Hydrant Repair" by N. B. Cunningham (E. V. Leverett, discussor).

Arkansas Water and Sewerage Conference

"Repairs of a Distribution System" by H. E. Nunn (N. H. Phillips, discussor).

"Effect on Consumers of Chemical Contents of Potable Waters" by Harrison Hale (Fletcher Thompson Discussor).

"Safety in Handling Liquid Chlorine" by E. W. Schouten (R. R. Pittman, discussor).

"Licensing Water Works Operators" by R. C. Dohe.

"Threshold Odors" by John P. Harris.

"Distribution of Plankton in Lakes" by David C. Chandler.

"Food-chain of Fishes" by F. D. Black.

"Recent Developments in Water Works Field" by R. E. McDonnell.

"Denver Sewer Plant" by E. L. Filby.

"Water Meter Repairs" by L. A. Jackson and G. H. Sutton.

"Exhibit and Demonstration of Water Meters in Laboratory" (Charles Berry, Egmont S. Smith, R. C. Wray, James G. Bailey).

"Swimming Pools" by A. H. Ullrich.

"Suggested Improvements in Design and Operation of Water Plants in Arkansas" by F. L. McDonald.

"Twenty Years of Water and Sewerage Progress in Arkansas" by M. Z. Bair and F. L. McDonald.

"Rate Making" by Max Mehlburger.

New officers:

For 1938-1939 the following officers were elected:

Chairman—Fletcher Thompson, Supt. of Water, Clarksville.

Vice-Chairman—H. S. Peck, Supt. of Water, Fort Smith.

Secretary—Harrison Hale, Univ. of Arkansas, Fayetteville.

The Executive Committee consists of: Chairman, W. R. Spencer, Fayetteville; H. H. Clayton, Lewisville; M. H. Phillips, Paragould; Chas. Williams, Helena, and E. T. Brown, Fayetteville.

A committee to study the question of licensing water works operators, and to report in 1939 was appointed: L. A. Jackson, Little Rock (Chairman); Lloyd M. Rebsamen, Jonesboro; F. L. McDonald, Little Rock; Ed. V. Leverett, Conway; W. R. Spencer, Fayetteville. The attendance committee for 1939 is: H. T. Buchanan, Little Rock; F. L. McDonald, Little Rock; R. J. Rhineheart, Pine Bluff; H. H. Clayton, Lewisville; L. O. Ray, Mulberry; M. H. Phillips, Paragould.

The Conference, as usual, was held under the auspices of the General Extension Division of the University of Arkansas, in cooperation with the State Board of Health and the Departments of Civil and Chemical Engineering of the University.

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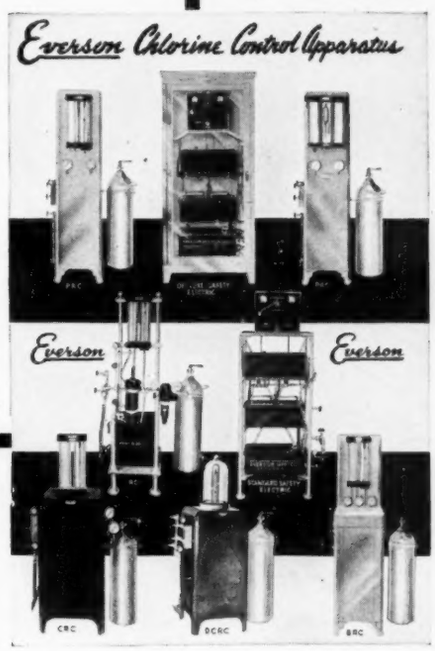

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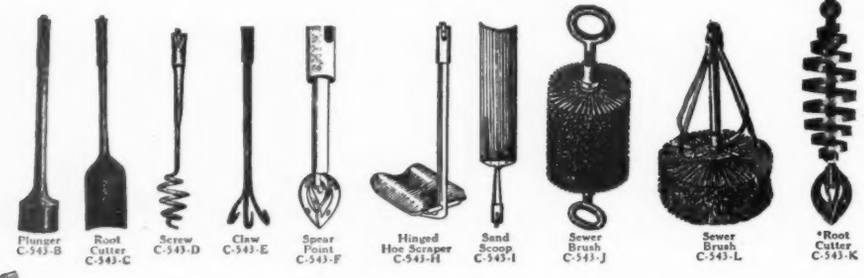
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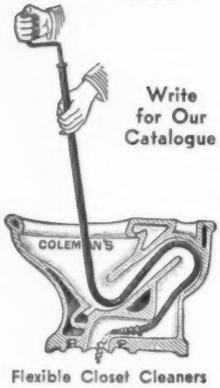

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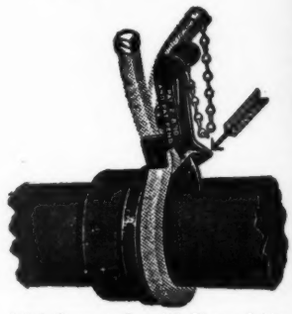
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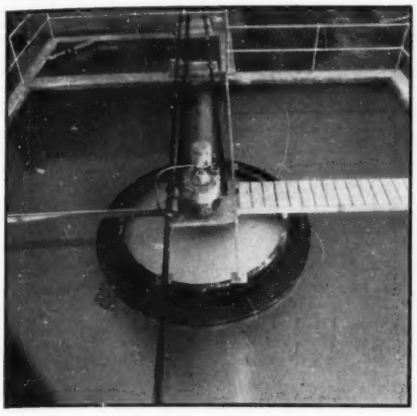
EQUIPMENT NEWS

The "Accelator," an Improved Water Softener

The "Accelator," developed by International Filter Co., constitutes an advancement of note in water softening. In this novel softening unit the principles of mass action and catalysis are combined in affecting a new and more rapid method of clarification. It is offered on the guarantee of more effective treatment, not only in softening but also in water stabilization, iron removal, pH adjustment and other types of water treatment.

Raw water introduced into the reaction chamber of the Accelator is mixed there



Tank Equipped With International's "Accelator"

with the circulating slurry of previously precipitated solids, and the proper dose of whatever chemicals the treatment requires. New solids resulting from chemical reactions are formed in the reaction chamber in the presence of the tremendous depositing surface of the circulating sludge particles. As a result, the reactions involved are markedly hastened, and a large portion of the new solids is deposited on the old particles, instead of forming as new small ones. The augmented slurry circulates from the reaction chamber to the outer portion of the tank where clarification takes place, the treated water separating and rising uniformly to the clear water launders. The slurry left behind circulates inwardly to the reaction chamber where it functions again in treatment.

Excess solids in the slurry pool pass over a skimming weir into a concentrator, from which they are withdrawn as a thick sludge. A proper volume of slurry is thus maintained in the treating tank.

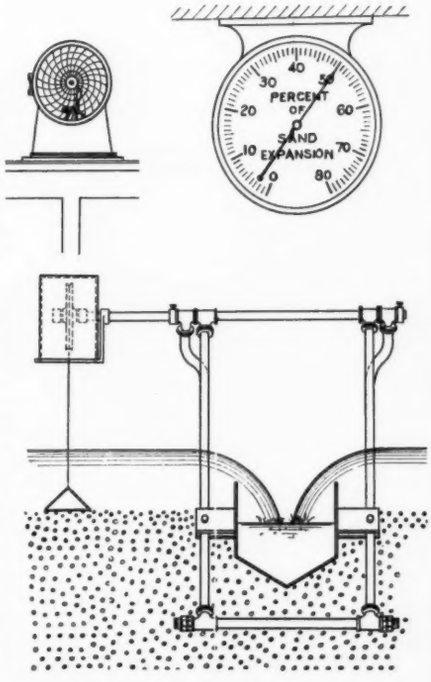
Time and space requirements are greatly reduced by the rapidity with which reactions and clarification take place in the Accelator. As a result, Accelator treating tanks have approximately one-fourth the area and volume of tanks heretofore provided for mixing, coagulation and sedimentation. Furthermore, the treated water is of better quality; and, too, savings are reported in the amounts of chemicals required. For literature which more adequately illustrates and describes International's "Accelator"—write, International Filter Co., 59 E Van Buren St., Chicago.

Simplex Sand Expansion Indicator

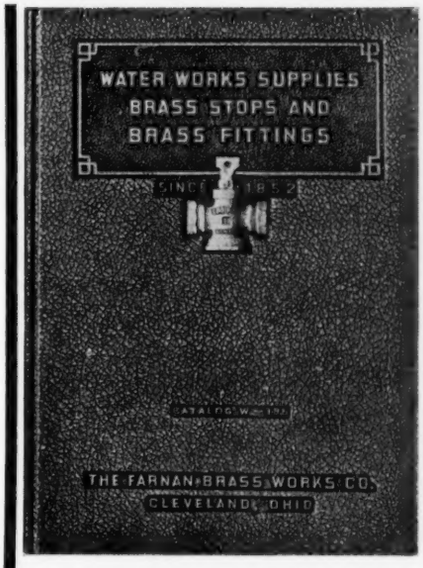
Simplex Valve and Meter Co. of Philadelphia, have perfected a useful Sand Expansion Indicator which has for the past two years been under development at the Allentown, Pa. filtration plant under direction of Harry J. Krum, Chemist in charge.

The distinctive advantages of the sand expansion indicator, in the proper washing and maintenance of filter beds and economy in wash-water use, have been recounted in an article by Krum and Jones in the October, 1937, issue of WATER WORKS AND SEWERAGE—to which the reader is referred for details of design and functioning, and advantages noted in its use. Suffice it to say here that it has become well proven that prescribed rates of wash water application are not sufficient unless it can be shown that the sand bed is adequately expanded (floated) to insure free grain scrubbing. However, of overly expanded too great spaces occur between the grains and grain collisions are fewer, indicating need of control. It has also been established that the judgment of shift operators is not always the best in arriving at the correct washing rate, and "guessing" is subject to wide variations. Further, that varying water temperature requires changing rates. The Expansion Indicator was perfected to eliminate the human equation and established more precise and readily duplicated operations in filter maintenance the year around.

Simplex Valve and Meter Company now have gone into production of the Expansion Indicator and are offering complete units, as here illustrated. Note the large clear vision dial for the end of the operating gallery, indicates bed-expansion rather



Simplex Sand Expansion Gauge for Filter Wash Control



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than wash rate in gallons or inches rise. For the smaller plants a compact post-type indicator is provided for a position near the filter wash control lever. Optional, is the recording instrument, shown above, which has its value in providing records of wash time, period of wash and degree of bed expansion. The usual wash meter records the rate and total volume of wash water used.

It will be noted that the little inverted cone float, buoyed up by the liquefied (floating) sand bed, is the "heart" of the Expansion Indicator. It was the gravity and correct shape of this little "gadget" which required many trials and re-design by the inventors, in perfecting accuracy and dependability of the Indicator.

A reprint of the original article above referred to and an illustrated bulletin, revealing details and specific advantages of the new Sand Expansion Indicator, can be had by writing Simplex Valve and Meter Co., 68th and Upland Streets, Philadelphia, Pa.

▼

New "Self-Priming" Centrifugal Pumps

The Deming Company of Salem, Ohio, has perfected a new line of completely automatic "Self-Priming" Centrifugal Pumps, starting with portable models of 600 gal./hr. capacity.

A noteworthy feature of the new pumps is the rapid and positive priming, every priming operation being completely automatic and dependable, with positive automatic shut-off recirculating the water. Impellers are semi-enclosed non-clog type.

The stationary, electric motor and belt driven, units cover a range of 16 capacities from 10 to 300 gallons per minute. These pumps are particularly adapted for sump-pump service with float switch control, and many other dewatering requirements where foot valves are objectionable.

The gasoline engine units are portable and especially designed for use by contractors, and on maintenance and repair work; for pumping sewage effluent at treatment works, etc. One portable type is mounted on steel trucks with disc steel hubs and pneumatic tires. Capacities of this model range from 7,000 to 20,000 gallons per hour.

Another smaller portable unit, known as the "Light-Weight" model, is equipped with a carrying handle. Weighing only 55 pounds, it can be easily carried by one man. This unit is complete and exceptionally economical to operate as it runs continuously from eight to twelve hours on one gallon of gasoline.

This new line of Deming "Self-Priming" Centrifugal Pumps are treated in detail in Bulletin No. 3,000. For a copy write, The Deming Company, Salem, Ohio.

▼

WITH THE MANUFACTURERS

Nichols Takes Over Decarie Incinerator

The Nichols Engineering and Research Corporation, 40 Wall Street, New York City, have recently announced the acquisition of the basket type Decarie Incinerator, for refuse, garbage and rubbish destruction, formerly offered by the Underpinning and Foundation Company of New York.

With the addition of the long established and well known Decarie incinerator, the Nichols Corporation is now in position to offer proven equipment for the complete disposal (incineration) of all types of municipal refuse.

The Nichols' Multi-Hearth (rabbling type) Incinerator was transplanted from the metallurgical field into the municipal field with remarkable rapidity of acceptance, following its proven performance at Dearborn, Michigan under City Engineer Mark B. Owen, who has since become Vice President of the Nichols Engineering and Research Corp. Mr. C. W. Nichols, Sr., is Chairman of the Board of "NERCO," and Mr. H. J. Hartley, President of the company, will continue to have charge of sales and service to municipalities and engineering firms.

Messrs. Morris, Woodman, Buffington, and Burgess, former engineers of the Decarie Corp., are now associated with the Nichols Corporation, with headquarters at 40 Wall St., New York City.

▼

Globe Phone Announces Expansion Program

The Globe Phone Mfg. Corporation of Reading, Mass., has recently established executive offices at 11 West 42nd St., New York City. In its program of expansion, plans are also under way to open an additional plant in New York, according to advices from Mr. O. H. Allen, President of the Company.

Globe Phone Mfg. Corporation has long been established in Reading, Mass., and in fact was a pioneer in introducing electrically operated pipe finding and leak locating equipment into the water works field. Best known, is Globe's Geophone Leak Locator; Radio Pipe Finder; Aqua Pipe Phone; Globe Dipping Needle.

Under the present expansion program, new distributor outlets are being selected with an aim of providing centralized distribution and service facilities for Globe equipment for water works and manufacturing plants in all sections of the country. The Reading, Mass., plant will continue production of Globe precision products, as in the past, under the direction of Mr. W. C. Mooney.

▼

Texas Chlorine for Texans

The first car of liquid chlorine manufactured in Texas very appropriately went to the Dallas Texas Water Works. It was produced in the new $2,000,000 chlorine plant of Southern Alkali Corporation of Corpus Christi, Texas.

Due to the lesser freight haul, Texas municipalities are rejoicing over the fact that henceforth liquid chlorine will cost them considerably less than heretofore, which will widen its use in sewage treatment as well as water purification. Those plants employing chlorine in production of coagulant (chlorinated-copperas or chlorinated scrap iron) such as is being practiced at Dallas, Houston, El Paso, Dennison, Oklahoma City, and Phoenix, Arizona, and other cities in the Southwest, will be especially benefited by "Southwest Chlorine for the Southwest."

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Your help is wanted in keeping track of the 1938 Treatment Trailer. Two %Proportioneers% left Providence Office Mar. 22nd with Treatment Trailer, leaving no clue except short note, "It's the gypsy in us." Should you locate these men, Henry Armbrust or Jeff Corydon, in your city, be sure to inspect Treatment Trailer —illustrating "a good way to feed many chemicals." %PROPORTIONEERS%.

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MUNICIPAL WATER PLANT	Richmond, Va.
MUNICIPAL WATER PLANT	Springfield, Ill.
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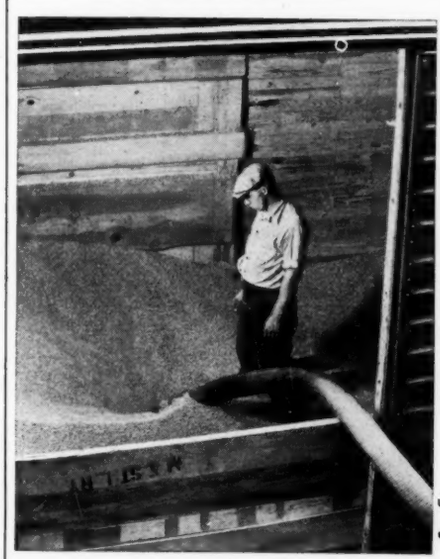
MUNICIPAL WATER PLANT (2 installations)	Milwaukee, Wis.
MUNICIPAL SEWAGE DISPOSAL PLANT	Oklahoma City, Okla.
MUNICIPAL SEWAGE DISPOSAL PLANT	Denver, Colorado
MUNICIPAL WATER PLANT	Covington, Ky.
MUNICIPAL WATER PLANT	Ann Arbor, Mich.
CLAYTON SEWAGE DISPOSAL PLANT	Atlanta, Ga.
WESTERLY SEWAGE DISPOSAL PLANT	Cleveland, Ohio
EASTERLY SEWAGE DISPOSAL PLANT	Cleveland, Ohio
MUNICIPAL WATER PLANT	Benton Harbor, Mich.
MUNICIPAL WATER PLANT	Warren, Ohio
MUNICIPAL SEWAGE DISPOSAL PLANT	Detroit, Mich.



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LIQUID CHLORINE

MEETINGS SCHEDULED:

Apr. 24-28—NEW ORLEANS, LA. (Hotel Roosevelt).
American Water Works Association. (Annual Convention.) Executive-Secretary H. E. Jordan, 22 East 40th St., New York City, N. Y.

May 9—DANBURY, CONN. (Hotel Green).
New England Sewage Works Association. (Spring Meeting.) Sec'y, Frank W. Gilcreas, State Dept. of Health, Albany, N. Y.

May 12—BRATTLEBORO, VT.
New England Water Works Association. Sec'y, Frank J. Gifford, 613 Statler Bldg., Boston, Mass.

May 13-14—BOZEMAN, MONT. (Baxter Hotel).
Montana Section, A.W.W.A. Sec'y, H. B. Foote, State Board of Health, Helena, Mont.
(2 Day Short School for Water Operators Precedes this Meeting.)

May 19-20—BALTIMORE, MD. (Hotel Emerson).
Maryland-Delware Water & Sewage Works Assn. Sec'y, A. W. Blohm, Asst. Engr., State Dept. of Health, Baltimore, Md.

May 19-21—SPOKANE, WASH. (Hotel Davenport).
Pacific Northwest Section A.W.W.A. Sec'y, Fred Merryfield, Oregon State College, Corvallis, Ore.

May 23-25—DAYTONA BEACH, FLA. (Williams Hotel).
Florida Section A.W.W.A. Sec'y, J. R. Hoy, 404 Hildebrandt Bldg., Jacksonville, Fla.

May 25—NEW MILFORD, N. J. (Hackensack Water Co. and Ridgewood Valley Plants—Dinner at Ridgewood Elks Club).
New Jersey Section A.W.W.A. Sec'y, Prof. H. N. Lendall, College of Engineering, Rutgers University, New Brunswick, N. J.

June 3-4—BUFFALO, N. Y. (Hotel Lafayette).
New York State Sewage Works Association. Sec'y-Treas., A. S. Bedell, State Dept. of Health, Albany, N. Y.

June 7-9—STATE COLLEGE, PA. (State College).
Penna. Sewage Works Association. Sec'y, L. D. Matter, Kirby Health Center, Wilkes-Barre, Pa

Sept. 12-13—CASPER, WYOMING (Townsend Hotel).
Rocky Mountain Section A.W.W.A. Sec'y, B. V. Howe, State Office Bldg., Denver, Colo.

Sept. 13-16—BOSTON, MASS. (Hotel Statler).
New England Water Works Association. (57th Annual Convention.) Sec'y, Frank J. Gifford, 613 Statler Bldg., Boston, Mass.

Sept. 14-16—SAGINAW, MICH.
Michigan Conference Water Purification. (Annual Convention.) Sec'y-Treas., R. J. Faust, Michigan Dept. Health, Lansing, Mich.

Sept. 29-Oct. 1—MINNEAPOLIS, MINN. (Hotel not announced).
Minnesota Section A.W.W.A. Sec'y, R. M. Finch, 416 Flour Exchange, Minneapolis, Minn.

Oct. 2-5—NEW YORK CITY (Hotel not announced).
American Public Works Association. (Congress.) Executive-Director, Frank W. Herring, 1313 East 50th St., Chicago, Ill.

Oct. 6-7—WASHINGTON, D. C. (Hotel not announced).
Four States Section A.W.W.A. Sec'y, Carl A. Hechmer, Dept. Engr., Washington Suburban San. Distr., Hyattsville, Md.

Oct. 6-8—HARTFORD, CONN. (Hotel Bond).
New York State Sewage Works Association. Sec'y, A. S. Bedell, State Board of Health, Albany, N. Y.
(Meeting Jointly with)
New England Sewage Works Association. Sec'y, F. W. Gilcreas, State Dept. of Health, Albany, N. Y.

Oct. 13-15—DES MOINES, IOWA (Hotel Fort Des Moines).
Missouri Valley Section A.W.W.A. Sec'y, Earl L. Waterman, University of Iowa, Iowa City, Ia.

Oct. 17-20—OKLAHOMA CITY, OKLA. (Hotel Biltmore).
Southwest Section A.W.W.A. Sec'y, L. A. Quigley, Supt., City Water Works, Fort Worth, Texas.

Oct. 25-28—KANSAS CITY, MO.
American Public Health Association. Executive-Secretary, Reginald M. Atwater, M.D., 50 West 50th St., New York City.

CATALOGS AND LITERATURE RECEIVED

[Any of the publications reviewed in this section can be secured from or through Water Works and Sewerage, if such be desirable.]

"Pollard's Catalog"—Celebrating its 100th year of service, Joseph G. Pollard Company (established 1837), have issued a 100th Anniversary Catalog—one of the most complete ever issued in the history of the "House of Pollard," which handles a wide variety of water works and sewerage equipment, termed "Pollard's Complete Line." It is profusely illustrated and each item carries a distinctive Figure Number (also telegraphic code number) for simplification in ordering and insuring delivery of the correct item in rush or emergency deliveries. To examine the complete index, the "A's" start with Asbestos Joint Runners and the "Y's" end with Yarning Irons. In between are such a variety as Braces (trench), Chisels and Copper-setters, Dog Chisels and Dipping Needles, Expanding (Sewer) Root Cutters and Electric Thawing Machines, Pipe Finders and Flow Gages, Geophones, Hammers and Hose, Lanterns and Leak Detectors, Meter Books and Gas Masks, Portable Pumps and Pipe Pushers, Shovels and Sewer Cleaning Rods, Tool Carts and Tapping Machines, Wrenches and Welding Machines. These "Sears Roebuck" general supply catalogs are always as valuable as they are interesting—and useful—and Pollard's is no exception. For easy location it has a flaming red cover. A copy can be had by writing James G. Pollard, Inc., 142 Ashland Place, Brooklyn, N. Y.

"U. S. Mechanical Joints"—Are effectively described and illustrated in a brand new 36-page catalog from U. S. Pipe and Foundry Co. The U. S. Joint is pictorially taken apart and put together step-by-step, and in some detail, for the benefit of the reader. Specifications are full and easy to follow. The U. S. Joint for pipe and fittings is built on the principle of the stuffing-box, in which the gasket is a wedge shaped rubber ring put under compression with a flange pulled home by corrosion resistant bolts. It has all of the merits of the bell and spigot joint (that it is) with flexibility added. A variety of its applications are pictured. Various fittings, tees, crosses, et al., are illustrated, with tables of dimensions and weights given in the specifications. Stressed is the fact that the U. S. Mechanical Joint is with-it-all a bell and spigot joint (bolt-locked) in which flexibility has been added with bottle tightness insured. For "U. S. Joints, Pipe and Fittings," write U. S. Pipe and Foundry Co., Burlington, N. J.

"Armco Sewers"—Is a 48-page profusely illustrated bulletin from Armco Culvert Mfgrs. Assn., which effectively presents the story of Armco Corrugated Paved Invert Pipes for sewers and drainage systems. It presents a discussion of sewer design and strength, the advantage of *flexibility* and economy of long length corrugated ingot iron pipes in sewer construction. A chapter is devoted to presenting the very satisfactory service record of better than 5,000,000 feet of the Paved Invert Corrugated Pipes, from 12 to 84 inches, in 1,000 cities. Further, how the bituminous coated pipes have withstood alkali and acid wastes and hydrogen sulphide in sewer gas. Methods of making joints, inserting fittings, construction of sewers and fabricated all-metal

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Through the use of the Air Relay the Register can be located at a distance from the Tube, or can be grouped with other Registers at a central point. Low head installation can be operated without float pipes, head pipes, or detached wells.

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The Air Relay Transmission System is equally suitable for your new or existing installations. Lets talk it over!

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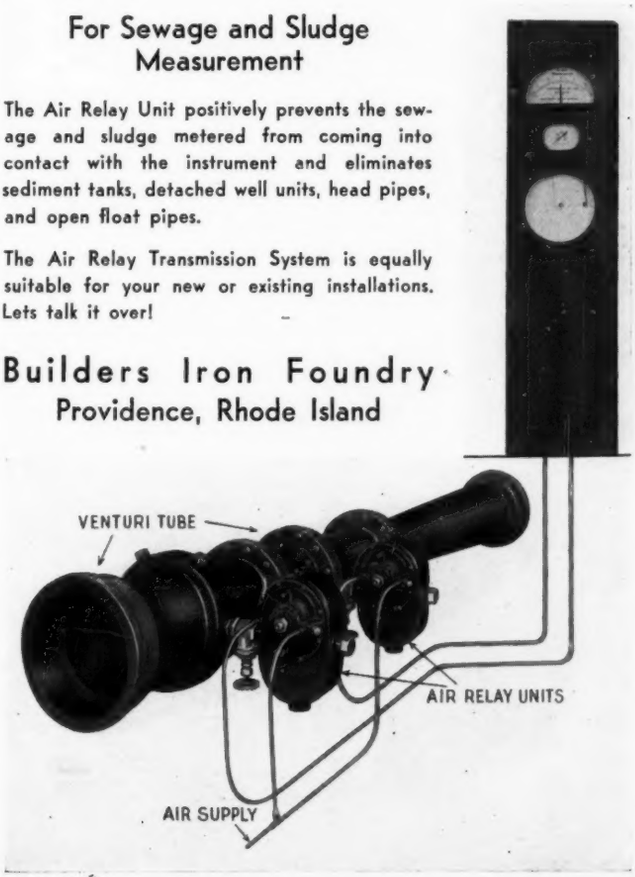

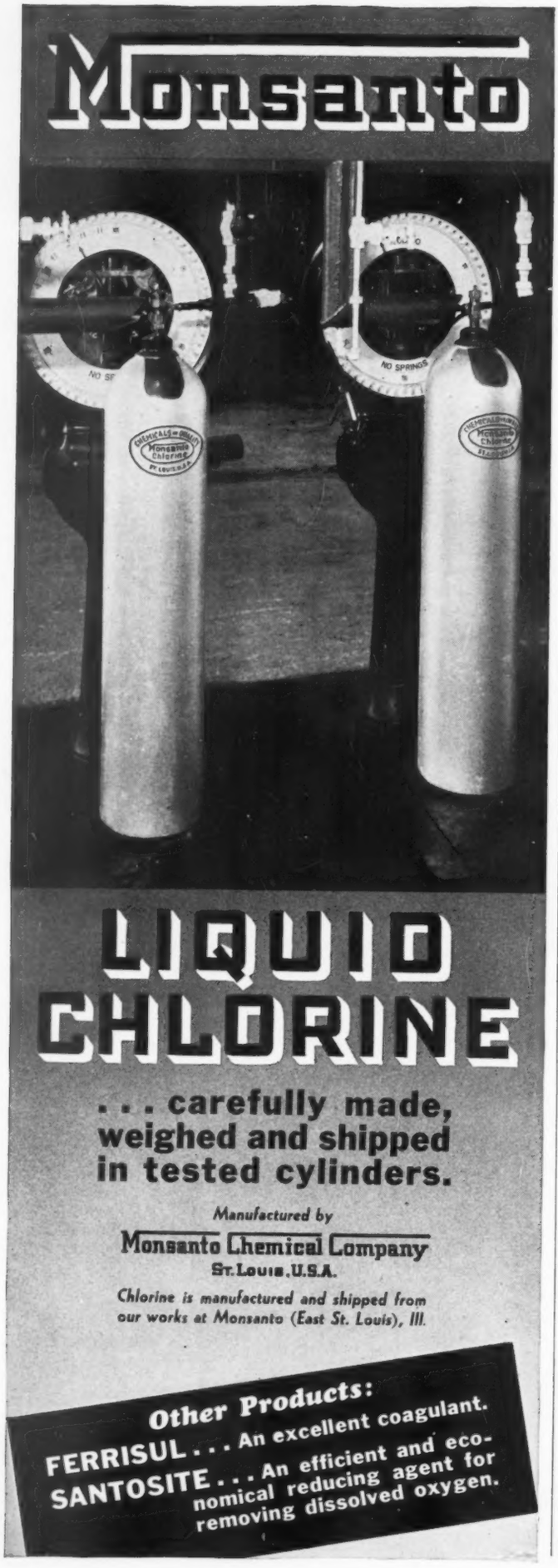
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manholes are described. A chapter dealing with comparative costs of sewer construction of various materials is especially illuminating—this being followed by several pages of "General Installation Data," with graphs revealing slope, velocity and carrying capacities of sewers based on Manning's Formula, and involving various values of coefficient "N." The final chapter reveals complete specifications. (Elsewhere in this issue a story of flood damage to California sewers, and repair methods, reveals the usefulness of corrugated pipes in reconstruction of damaged sewers.—Ed.) For a copy of worth-having "Armco Sewers" write Armco Culvert Mfgrs. Assn., Middletown, Ohio.

"Anaconda Tubes and Fittings"—Is a new brochure, from the American Brass Co., which presents the merits of copper pipe, copper tubing and fittings of the solder-type for the rigid tubes and the flared-end compression fittings for the flexible copper tubing or thin walled conduit tubing. In the rear of the brochure are illustrated suggestions covering the procedure of making up copper tube lines with solder-type fittings and valves. Another set of pictures reveals the step-by-step procedure in making up a line with flared end tube and compression type fittings. Charts of specifications give diameters, weights, et al., of type "K," "L" and "M" tubing, in sizes from ⅛th to 8 inches in diameter. For copy of "Anaconda Copper Tubes and Fittings"—write, American Brass Co., Waterbury, Conn.

"Plastex Enamels"—Is the title of a brochure from Steel Protection and Chemical Company of Indianapolis, which describes and presents specifications covering their "Plastex" protective coatings. The base of "Plastex" is plasticized coal-tar pitch, from which a "Plastex Enamel" from "A" to "S" is produced for every purpose. The new brochure, introducing "Plastex" to water works and sewerage engineers and operators, gives an interesting picture of what these coatings really are—and why—; also, methods of application and why. Detailed specifications cover the three most important enamels Plastex "A," "H," "S." Then is presented "Plastex" (cold application) Paints and "Plastex Putty." Finally, "Protex" paint in copper, gold, silver and several colors. For a copy of "Plastex" write Steel Protection & Chemical Co., Inc., Merchants' Bank Bldg., Indianapolis, Ind.

"Vitrex and Amolac"—Are presented in a brochure and a leaflet recently received from Atlas Mineral Products Co. "Vitrex" is the acid resistant cement (silicate base) which Atlas so successfully introduced into the industrial field some years ago. It has been widely used in setting brick linings in steel tanks, used for acid storage and steel "pickling" in hot acid, storing or making ferric chloride solutions, and similar operations which are extra hard on acid proof tank linings. The brochure tells of the properties of "Vitrex," how it is prepared as mortar and applied as protective plaster coat, but more importantly in laying up brick or tile work in tank linings, sewer linings, construction of towers or stacks. Also Atlas Acid Proof Brick are described. To engineers in the water and sewage fields, as in the industrial field, this brochure has value. Accompanying the "Vitrex" brochure is a leaflet describing "Amolac"—a protective elastic and tenacious coating for metal or concrete structures—which has as its base a synthetic rubber-like resin. "Amolac" is also offered as a protection for concrete sewer pipe if applied to the *dry* pipe. For general use it is available in black, red, or green color. For copies of "Vitrex" and "Amolac" write Atlas Mineral Products Company, Mertztown, Pa.

"Insulbrix"—Is the trade name of Quigley Co.'s light weight low heat storage but highly insulating fire-

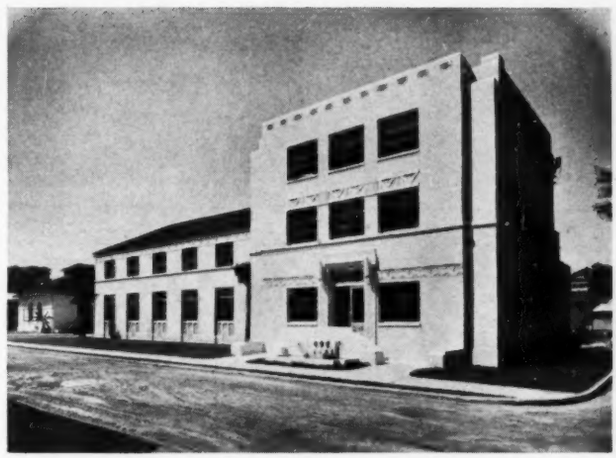
brick; also the caption of a new 8 page bulletin describing the characteristics and advantages from use of "Insulbrix" to improve boiler, furnace and incinerator operation, to produce economy and enhance flexibility. Amongst the chief advantages are (1) the doing away with thick walls of heavy refractories which are sluggish to heat and slow to respond to load variations; (2) fuel, time and labor saved, with higher efficiencies and lower operating and maintenance costs. Adaptation of "Insulbrix" are thoroughly described and effectively illustrated in Bulletin 328. If you have furnace or incinerator troubles or problems write Quigley Company, 56 W. 45th St., New York.

"Han-Dee Maintenance and Repair Trailers"—In a new bulletin from Littleford of Cincinnati are presented several styles of their well known and well constructed "Han-Dee" Tool Boxes, mounted on air wheels for quick and easy transportation to points where needed in maintenance, repair and emergency work on water and sewage systems. There are several models of Littleford's all-steel Trailer Tool Boxes illustrated and described—a size and model for every need; every pocketbook. The 8-foot long model has 35 compartments (all easy to get at), and the 6-foot model 25 compartments. There is a 4-ft. long model with roller bearing wheels and solid rubber tires. The latter is Littleford's Utility Box for a variety of uses at the curb, such as routine hydrant and valve inspection and maintenance, or service-line work. An enclosed leaflet presents Littleford's lead and joint-compound melting furnaces. For Bulletin L-6 "Han-Dee Boxes" write Littleford Bros., Cincinnati, Ohio.

"Sewer Maintenance Equipment"—In a variety of units, styles, and patterns, sewer cleaning tools are illustrated and described in the new 1938 catalog of Alan J. Coleman, Chicago manufacturers of plumbers and sewer maintenance specialties. The newest item is the Coleman Rotating Spear Point for heading flexible steel sewer rods. Another featured product are the Coleman Rods, coupled with Coleman's Frictionless Couplings. Other items are Root Harpoons and Cutters; Self Propelling Ferrets and Revolving Flushing Nozzles; and a variety of cleaning rod heads. For a copy of this complete catalog, write Alan J. Coleman, 120 W. Illinois St., Chicago.

"Here's How"—Is the title of a bulletin from S. R. Dresser Mfg. Co., which gives a very complete and interesting story of Dresser "No-Thread" (rubber gasketed) Coupling for small pipe jointing. It describes the coupling in detail and reveals its ease of application, and many uses and adaptations in making replacements and repairs easily and without the need for threading or precision cutting of the pipes. Then follows three pages of pictured "No-Thread" Fittings with exact dimensions and prices. For a copy of *"Here's How,"* write S. R. Dresser Mfg. Co., Bradford, Pennsylvania.

"Sewer Rodding with Flexibles"—In a new bulletin, Flexible Sewer-Rod Co. of Los Angeles presents their story of the "Flexible." It is an all-steel sewer rod which is made up of screw jointed lengths of 3 foot steel rods, thereafter coiled for transportation and use in sewer maintenance work or carried in 9 foot sections for jointing as required at the point of use. Many tool-heads for the rod are pictured, including "Sand-Cups"; "Root Blades," et al. For the really tough job, between far separated manholes, a compact Power Drive for turning the flexible rod is offered. Axiom of the company is "Keep your men out of dangerous manholes"—with Flexibles. For a copy of the new bulletin, write Flexible Sewer-Rod Co., 622 E. 4th St., Los Angeles, Calif.



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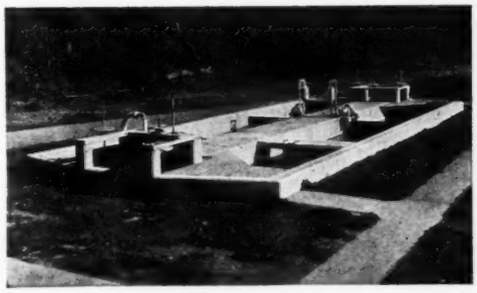

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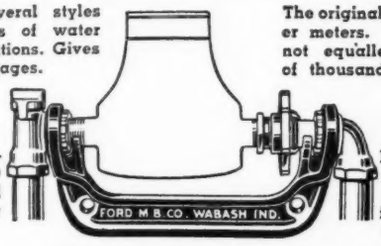

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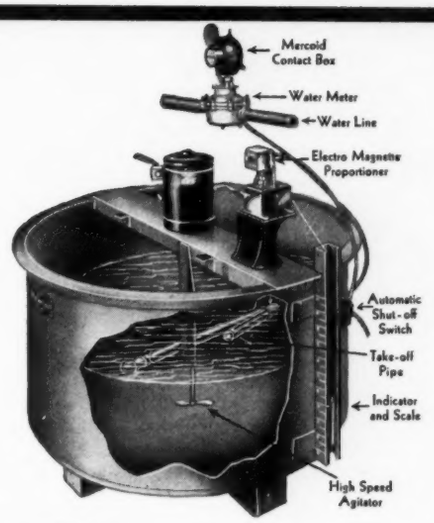

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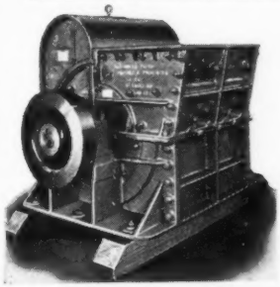

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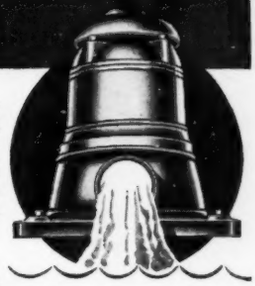

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This section has been prepared by Mr. L. H. Enslow, Editor of Water Works and Sewerage. It gives the equivalent of a handbook of data on the design, construction, operation and maintenance of water works and sewerage systems.

The contents are carefully selected matter from the files of Water Works and Sewerage and from other sources named in the text. In addition, a considerable effort has been made to secure the latest hydraulic tables and standards and the most economical methods. In a word, the same conscientious work has been put into the preparation of this Reference and Data Section as would be expected in a book devoted exclusively to the same purpose.

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CLASSIFIED INDEX of PRODUCTS

ABRASIVES
Carborundum Co., Niagara Falls, N. Y.
Norton Co., Worcester, Mass.

ACID, HYDROCHLORIC
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

ACID, SULPHURIC
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

ACTIVATED AND BLACK ALUM
Activated Alum Corp., 80 Broad St., New York City.

ACTIVATED CARBON
American Water Softener Co., Lehigh and 4th Sts., Philadelphia, Pa.
Cliffs-Dow Chemical Co., Marquette, Mich.
Darco Corporation, 60 E. 42nd St., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Industrial Chemical Sales Division, West Virginia Pulp & Paper Co., 230 Park Ave., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
L. A. Salomon & Bro., 216 Pearl St., New York City.

ACTIVATED CARBON DOSAGE DETERMINATION
Darco Corp., 60 E. 42nd St., New York City.

ACTIVATED SLUDGE EQUIPMENT
American Well Works, Inc., Aurora, Ill.
Carborundum Co., Niagara Falls, N. Y.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Norton Co., Worcester, Mass.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Simplex Valve & Meter Co., Philadelphia, Pa.

AERATION APPARATUS
American Water Softener Co., Lehigh & 4th Sts., Philadelphia, Pa.
American Well Works, Inc., Aurora, Ill.
Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lancaster Iron Works, 122 E. 42nd St., New York City.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Norton Co., Worcester, Mass.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th and Upland, Philadelphia, Pa.
Vogt Mfg. Co., Louisville, Ky.

AGITATORS
American Water Softener Co., Lehigh and 4th Sts., Philadelphia, Pa.
Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Dorr Co., Inc., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., East Chicago, Ind.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Vogt Mfg. Co., Louisville, Ky.

AIR COMPRESSORS
(See Compressors, Air)

AIR LIFT PUMPING SYSTEMS
Worthington Pump & Machy. Corp., Harrison, N. J.

AIR VALVES
(See Valves, Air)

ALLOY CAST IRON PIPE AND FITTINGS
American Cast Iron Pipe Co., Birmingham, Ala.
American Radiator Co., 40 W. 40th St., New York City.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Lynchburg Foundry Co., Lynchburg, Va.
U. S. Pipe & Foundry Co., Burlington, N. J.

ALTERNATORS, ELECTRIC
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Clark Controller Co., 1146 E. 152nd St., Cleveland, O.

ALUM, AMMONIA
Activated Alum Corp., 80 Broad St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

ALUM, BLACK
Activated Alum Corp., 80 Broad St., New York City.

ALUM, FILTER, COMMERCIAL, IRON-FREE
Activated Alum Corp., 80 Broad St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

AMMONIA, ANHYDROUS & AQUA
The Barrett Co., 40 Rector St., New York City.
Great Western Electro-Chemical Co., 9 Main St., San Francisco, Calif.
Mathieson Alkali Wks., Inc., 60 E. 42nd St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

AMMONIATORS
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Pardee Engineering Co., Long Island City, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.

ANALYTICAL WARE
Carborundum Co., Niagara Falls, N. Y.
Norton Co., Worcester, Mass.
Phipps & Bird, 915 E. Cary St., Richmond, Va.

ANTHRAFILT
Hudson Coal Co., Scranton, Pa.

AQUA TESTER
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.

ARCH TYPE SEWERS
Armco Culvert Mfrs. Assn., Middletown, Ohio.

ASBESTOS-CEMENT PIPE
Johns-Manville Co., 22 E. 40th St., New York City.

ASH AND COAL HANDLING MACHINERY
Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Fuller Co., Catasauqua, Pa.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Koppers Rheolaveur Co., Pittsburgh, Pa.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

AUTOMATIC FILTER AND SOFTENER CONTROLS
American Water Softener Co., Lehigh & 4th Sts., Philadelphia, Pa.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
International Filter Co., 50 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., Philadelphia, Pa.

BACK FILLERS
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

BAR SCREENS
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Filtration Equipment Corp., 10 E. 40th St., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

BASE-EXCHANGE SILICATE
Graver Tank & Mfg. Co., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.

BEARINGS
Chain Belt Co., Milwaukee, Wis.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

BELTS, SEWER PIPE
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

BENTONITE
American Colloid Co., 363 W. Superior St., Chicago, Ill.

BINS, STORAGE
Chain Belt Co., Milwaukee, Wis.
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Graver Tank & Mfg. Co., East Chicago, Ind.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Lancaster Iron Works, Inc., 122 E. 42nd St., New York City.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

BITUMINOUS COATINGS AND LININGS
Barrett Co., 40 Rector St., New York, N. Y.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Inertol Co., Inc., 401 Broadway, New York City.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.
Wailes Dove-Hermiston Corp., 17 Battery Place, New York City.

BLACK ALUM
Activated Alum Corp., 80 Broad St., New York City.

BLEACHING POWDER
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

BOILER BLOWOFF APPARATUS
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Permutit Co., 330 W. 42nd St., New York City.

BOILER FEED PUMP CONTROL
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.

BOILER FEEDWATER TREATMENT
Activated Alum Corp., 80 Broad St., New York City.
American Water Softener Co., Lehigh & 4th Sts., Philadelphia, Pa.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
La Motte Chem. Prod. Co., Baltimore, Md.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
National Aluminate Corp., 6216 W. 66th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Penn.

BOILER FURNACE, BRICK
Carborundum Co., Niagara Falls, N. Y.
Norton Co., Worcester, Mass.

BOILER PLANT ACCESSORIES
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
So. Bend Foundry Co., So. Bend, Ind.

BOILERS, GAS
American Gas Prod. Corp., 40 W. 40th St., New York City.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

BOILERS, STEAM
American Radiator Co., 40 W. 40th St., New York City.

BOILER WATER CONTROL EQUIPMENT (pH & PHOSPHATE)
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
La Motte Chemical Co., McCormick Bldg., Baltimore, Md.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., Inc., 872 Linden Ave., Baltimore, Md.

BOILER WATER PURIFICATION APPARATUS
American Water Softener Co., Lehigh & 4th Sts., Philadelphia, Pa.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.

BOILER WATER TREATMENT APPARATUS
American Water Softener Co., Lehigh Ave. and 4th St., Philadelphia, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.

BOOKS, TECHNICAL, SCIENTIFIC, BUSINESS
John Wiley & Sons, 440 4th Ave., New York City.

BORER—UNDERGROUND PIPE INSTALLATION
Hydrauger Corp., Ltd., 116 New Montgomery, San Francisco, Cal.

BOXES, VALVES, ROADWAY, MITER
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
M. & H. Valve & Fittings Co., Anniston, Ala.
Modern Iron Works, Quincy, Ill.
Mueller Co., Decatur, Ill.
Trohn's Supplies, Inc., Mamaroneck, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.

BRAKES, MAGNETIC, MECHANICAL, HYDRAULIC
The Clark Controller Co., 1146 East 152nd St., Cleveland, Ohio.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

BRASS GOODS
(See also Pipe, Brass.)
American Brass Co., Waterbury, Conn.
Chase Brass & Copper Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago.
Farnan Brass Works Co., P. O. Box 6147, Cleveland, Ohio.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
Mueller Brass Co., Streamline Pipe & Fittings Div., Port Huron, Mich.
Mueller Co., Decatur, Ill.
Trohn's Supplies, Inc., Mamaroneck, N. Y.

BREECHINGS
Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Graver Tank & Mfg. Co., East Chicago, Ind.
Koppers Co., Western Gas Div., Ft. Wayne, Ind.
Lancaster Iron Works, Inc., 122 E. 42nd St., New York City.

BREECHINGS, STEEL
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Graver Tank & Mfg. Co., East Chicago, Ind.
Lancaster Iron Works, Inc., 122 E. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

BRICKS, ACID PROOF
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.

BUCKETS, DREDGING & EXCAVATING
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

BUCKETS, SEWER
Champion Corp., Hammond, Ind.

BUFFER SOLUTIONS & MIXTURES
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
LaMotte Chem. Prod. Co., Baltimore, Md.
W. A. Taylor & Co., 872 Linden Ave., Baltimore, Md.
Wilkins-Anderson Co., 111 N. Canal St., Chicago, Ill.

CALCIUM HYPOCHLORITE
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Gt. Western Electro-Chemical Co., 9 Main St., San Francisco, Calif.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

CALKING MACHINES AND TOOLS
Mueller Co., Decatur, Ill.

CARBON-ACTIVATED
(See Activated Carbon.)

CARBONATORS (Recarbonation).
Carborundum Co., Niagara Falls, N. Y.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Norton Co., Worcester, Mass.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

CASINGS & COVERINGS, STEAM PIPES
Johns-Manville, 22 E. 40th St., New York City.

CASTINGS, IRON, STEEL, ALLOY STEEL, ETC.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Chain Belt Co., Milwaukee, Wis.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill. (Bronze).
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Lynchburg Foundry Co., Lynchburg, Va.
McWane Cast Iron Pipe Co., Birmingham, Ala.
So. Bend Foundry Co., So. Bend, Ind.
U. S. Pipe & Foundry Co., Burlington, N. J.
Western Gas Div., Koppers Co., Ft. Wayne, Ind.

CASTINGS, MUNICIPAL
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Chain Belt Co., Milwaukee, Wis.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Lynchburg Foundry Co., Lynchburg, Va.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
McWane Cast Iron Pipe Co., Birmingham, Ala.
So. Bend Foundry Co., So. Bend, Ind.
Trohn's Supplies, Inc., Mamaroneck, N. Y.
U. S. Pipe & Foundry, Burlington, N. J.
R. D. Wood Co., Philadelphia, Pa.

CASTINGS, SPECIAL
Amer. Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Chain Belt Co., Milwaukee, Wis.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Lynchburg Foundry Co., Lynchburg, Va.
M. & H. Valve & Fittings Co., Anniston, Ala.
McWane Cast Iron Pipe Co., Birmingham, Ala.
Mueller Brass Co., Streamline Pipe & Fittings Div., Port Huron, Mich.
Trohn's Supplies, Inc., Mamaroneck, N. Y.
U. S. Pipe Foundry Co., Burlington, N. J.
R. D. Wood Co., Philadelphia, Pa.

CAST IRON PIPE
(See Pipe.)

CATCH BASINS, CORRUGATED IRON
Armco Culvert Mfrs. Assn., Middletown, Ohio.

CAUSTIC SODA
The Columbia Alkali Corp., Barberton, Ohio.
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Gt. Western Electro-Chemical Co., 9 Main St., San Francisco, Calif.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Solvay Sales Corp., 40 Rector St., New York City.

CEMENT
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.

CEMENT, ASBESTOS PIPE
Johns-Manville, 22 E. 40th St., New York City.

CEMENT LINED PIPE
(See Pipe.)

CEMENTS, ACID PROOF
Atlas Mineral Prod. Co., Mertztown, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Philadelphia Quartz Co., Philadelphia, Pa.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.

CEMENTS, SEWER PIPE
Atlas Mineral Prod. Co., Mertztown, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.

CEMENTS, WATER MAINS
Atlas Mineral Prod. Co., Mertztown, Pa.
Leadite Co., Girard Trust Bldg., Philadelphia, Pa.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.

CENTRIFUGE EQUIPMENT
Amer. Centrifugal Corp., 115 Broadway, New York City.

CHEMICAL CONVEYING EQUIPMENT
Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Fuller Co., Catasauqua, Pa.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

CHEMICAL FEED APPARATUS
American Water Softener Co., Lehigh Ave. and 4th St., Philadelphia, Pa.
Builders Iron Foundry, 9 Codding St., Providence, R. I.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.

CHEMICAL FEEDING EQUIPMENT
American Water Softener Co., Lehigh & 4th Sts., Philadelphia, Pa.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Fuller Co., Catasauqua, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Mach. Co., 4010 Penn Ave., Kansas City, Mo.
Pardee Engineering Co., Long Island City, N. Y.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan, Inc., Newark, N. J.

CHEMICALS FOR WATER PURIFICATION
Activated Alum Corp., 80 Broad St., New York City.
American Colloid Co., 363 W. Superior St., Chicago, Ill.
The Columbia Alkali Corp., Barberton, Ohio.
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., 230 Park Ave., New York.
Mathieson Alkali Works, Inc., 60 E. 42nd St., New York.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Monsanto Chemical Co., St. Louis, Mo.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Solvay Sales Corp., 40 Rector St., New York.

CHEMISTS AND ENGINEERS
(See Directory of Experts, page 306)

CHLORIDE, FERRIC
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Gt. Western Electro-Chemical Co., 9 Main St., San Francisco, Calif.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

CHLORIDE OF LIME
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

CHLORINATORS
(See also Hypochlorinators.)
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Pardee Engineering Co., Long Island City, N. Y.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan, Inc., Newark, N. J.

CHLORINE COMPARATOR
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
La Motte Chemical Prod. Co., McCormick Bldg., Baltimore, Md.
W. A. Taylor & Co., Inc., 872 Linden Ave., Baltimore, Md.

CHLORINE, LIQUID
The Columbia Alkali Corp., Barberton, Ohio.
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Gt. Western Electro-Chemical Co., 9 Main St., San Francisco, Calif.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.

Monsanto Chem. Co., St. Louis, Mo.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Solvay Sales Corp., 40 Rector St., New York.
Wallace & Tiernan, Inc., Newark, N. J.

CHLORINE CONTROL EQUIPMENT
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
La Motte Chem. Prod. Co., Baltimore, Md.
Pardee Engineering Co., 3915 29th St., Long Island City, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., 872 Linden Ave., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.

CHUTES, COAL, ETC.
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

CLAMPS AND SLEEVES, PIPE
Amer. Cast Iron Pipe Co., Birmingham, Ala.
McWane Cast Iron Pipe Co., Birmingham, Ala.
S. R. Dresser Mfg. Co., Bradford, Pa.

CLAMPS AND SLEEVES—RIVER
S. R. Dresser Mfg. Co., Bradford, Pa.

CLAMPS, BELL JOINT
S. R. Dresser Mfg. Co., Bradford, Pa.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
M. B. Skinner Co., So. Bend, Ind.

CLAMPS, PIPE REPAIR
S. R. Dresser Mfg. Co., Bradford, Pa.
M. B. Skinner Co., So. Bend, Ind.

CLARIFIERS, SEWERAGE AND WATER
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lancaster Iron Wks., 122 E. 42nd St., New York City.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York City.

CLEANING SEWER MAINS
Champion Corp., Hammond, Ind.

CLEANING WATER MAINS
National Water Main Cleaning Co., 50 Church St., New York City.

COAGULANTS
Activated Alum Corp., Curtis Bay, Baltimore, Md.
American Colloid Co., 363 W. Superior St., Chicago, Ill.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Monsanto Chem. Co., Merrimac Div., Everett Station, Boston, Mass.
Monsanto Chemical Co., St. Louis, Mo.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Philadelphia Quartz Co., Philadelphia, Pa.

COAGULATION CONTROL CHEMICALS
Activated Alum Corp., 80 Broad St., New York City.
American Colloid Co., 363 W. Superior St., Chicago, Ill.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
La Motte Chem. Prod. Co., Baltimore, Md.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Philadelphia Quartz Co., Philadelphia, Pa.
Wallace & Tiernan Co., Newark, N. J.

COAL & ASHES HANDLING MACHINERY
(See Ash & Coal Handling Machy.)

COAL ANTHRAFILT
Hudson Coal Co., Scranton, Pa.

COATINGS, ACID & ALKALI-PROOF FOR CONCRETE, STEEL AND WOOD
Barrett Co., The, 40 Rector St., New York City.
Ebony Paint Mfg. Co., 2925 E. 18th St., Kansas City, Mo.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Inertol Co., Inc., 401 Broadway, New York City.
Philadelphia Quartz Co., Philadelphia, Pa.
Tar & Chem. Div., Koppers Co., Pittsburgh, Pa.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.
Wailes Dove-Hermiston Corp., 17 Battery Place, New York City.

COATINGS AND LININGS
(See Bituminous Coatings and Linings.)

COCKS, CURB, METER, CORPORATION, ETC.
Chase Brass & Copper Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Farnan Brass Works Co., P. O. Box 6147, Cleveland, Ohio.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Trohn's Supplies, Inc., Mamaroneck, N. Y.
Union Water Meter Co., Worcester, Mass.

COLLECTORS (SLUDGE)
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Dracco Corp., Cleveland, Ohio.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.

COLLOIDAL CLAY
American Colloid Co., 363 W. Superior St., Chicago, Ill.

COLORIMETRIC ANALYSIS EQUIPMENT
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
La Motte Chemical Co., McCormick Bldg., Baltimore, Md.
W. A. Taylor & Co., Inc., 872 Linden Ave., Baltimore, Md.
Wilkins-Anderson Co., 111 N. Canal St., Chicago, Ill.

COMBUSTION INDICATORS AND RECORDERS
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.
Permutit Co., 330 W. 42nd St., New York City.

COMMINUTORS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

COMPARATORS (COLOR)
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
La Motte Chem. Prod. Co., Baltimore, Md.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., Inc., 872 Linden Ave., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.

COMPOUNDS, SEWER JOINT
Atlas Mineral Prod., Mertztown, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

COMPRESSORS, AIR
Fairbanks, Morse & Co., Inc., 600 S. Michigan Ave., Chicago, Ill.
Fuller Co., Catasauqua, Pa.
Gordon Smith & Co., Bowling Green, Ky.
Worthington Pump & Machy. Corp., Harrison, N. J.

COMPRESSORS, PORTABLE
Worthington Pump & Mach. Corp., Harrison, N. J.

CONCRETE
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.

CONCRETE, COLORING COMPOUNDS
Master Builders Co., 7016 Euclid Ave., Cleveland, Ohio.

CONCRETE HARDENER
Master Builders Co., 7016 Euclid Ave., Cleveland, Ohio.
Philadelphia Quartz Co., Philadelphia, Pa.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.

CONCRETE MIXERS
Chain Belt Co., Milwaukee, Wis.

CONCRETE PIPE
(See Pipe, Concrete.)

CONDENSERS (STEAM)
Amer. Cast Iron Pipe Co., Birmingham, Ala.
Koppers Co., Western Gas Div., Ft. Wayne, Ind.
Lynchburg Foundry Co., Lynchburg, Va.
U. S. Pipe & Foundry Co., Burlington, N. J.
Worthington Pump & Machy. Corp., Harrison, N. J.

CONTROLLERS, AUTOMATIC, ELECTRIC
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Newark, N. J.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

CONTROLLERS, FLOW, LEVEL, PRESSURE, RATIO, TEMPERATURE
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.

CONVEYORS AND CONVEYING EQUIPMENT
Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Fuller Co., Catasauqua, Pa.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Koppers Co., Engrg. & Constr. Div., Pittsburgh, Pa.
Link-Belt Mfg. Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

COOLING TOWERS
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.

COPPER, BRASS, BRONZE
American Brass Co., Waterbury, Conn.
Chase Brass & Copper Co., Waterbury, Conn.

COPPERAS
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.

COPPER SULPHATE
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.

COPPER TUBE, FLEXIBLE
American Brass Co., Waterbury, Conn.
American Radiator Co., 40 W. 40th St., New York City.
Chase Brass & Copper Co., Waterbury, Conn.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.

COUPLINGS AND CONNECTIONS, PIPE
S. R. Dresser Mfg. Co., Bradford, Pa.
Farnan Brass Works Co., P. O. Box 6147, Cleveland, Ohio.
Mueller Brass Co., Streamline Pipe & Fittings Div., Port Huron, Mich.
Mueller Co., Decatur, Ill.

COUPLINGS, FLEXIBLE
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
S. R. Dresser Mfg. Co., Bradford, Pa.
Jeffrey Mfg. Co., Columbus, Ohio.
Koppers Co., Bartlett Hayward Div., Baltimore, Md.

CRANES & HOISTS
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

CRUSHING MACHINERY
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

CULVERTS
American Cast Iron Pipe Co., Birmingham, Ala.
Armco Culvert Mfrs. Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City (Asbestos-Cement).
Lock Joint Pipe Co., Ampere, N. J.
Lynchburg Foundry Co., Lynchburg, Va.
U. S. Pipe & Foundry Co., Burlington, N. J. (Cast Iron)
R. D. Wood Co., Philadelphia, Pa.

CURB BOXES
Mueller Co., Decatur, Ill.
Modern Iron Works, Quincy, Ill.
Trohn's Supplies, Inc., Mamaroneck, N. Y.

DECHLORINATORS
Activated Alum Corp., 80 Broad St., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Omega Machine Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Newark, N. J.

DEWATERING PUMPS
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Worthington Pump & Mach. Corp., Harrison, N. J.

DIAPHRAGMS, PUMP
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Edson Corp., 49 D St., South Boston, Mass.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

DIFFUSERS—PLATES AND TUBES
Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Norton Co., Worcester, Mass.

DIGESTERS EQUIPMENT (SLUDGE)
Dorr Co., 570 Lexington Ave., New York City.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

DISTRIBUTORS (FILTER)
American Well Works, Inc., Aurora, Ill.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

DRAINS, STORM
Armco Culvert Mfrs. Assn., Middletown, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

Lock Joint Pipe Co., Ampere, N. J.
R. D. Wood Co., Philadelphia, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.

DRILLS, ROCK
Worthington Pump & Mach. Corp., Harrison, N. J.

DRIVES, CHAIN
Chain Belt Co., Milwaukee, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

DRIVES, VARIABLE SPEED
Reeves Pulley Co., Columbus, Ind.

DRY CHEMICAL FEEDERS
(See Chemical Feeding Equipment)

DRYERS
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Koppers Rheolaveur Co., Pittsburgh, Pa.
Nichols Eng. and Research Corp., 40 Wall St., New York City.

DRYERS, ROTARY
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

DRYERS, SAND, PORTABLE
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

DRYERS—SPRAY
Bowen Research Corp., Garwood, N. J.

ELECTRICALLY OPERATED GATE VALVES
Crane Co., 836 S. Michigan Ave., Chicago.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.

ELECTRIC MOTOR STARTERS
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

ELECTROMETER
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

ELEVATING AND CONVEYING EQUIPMENT
(See Conveyors & Conveying Equipment.)

ENGINEERS AND CHEMISTS
(See Directory of Experts, page 306)

ENGINES, DIESEL
Cooper-Bessemer Corp., Mt. Vernon, Ohio.
Fairbanks, Morse & Co., Inc., 600 S. Michigan Ave., Chicago, Ill.
Worthington Pump Corp., Harrison, N. J.

ENGINES, GASOLINE
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.

ENGINES, SEWAGE SLUDGE GAS
Cooper-Bessemer Corp., Mt. Vernon, Ohio.
Worthington Pump & Machy. Corp., Harrison, N. J.

FEED, CHEMICAL
(See Chemical Feeding Equipment.)

FEEDERS, ACTIVATED CARBON, FOR TASTE & ODOR CONTROL
American Water Softener Co., Lehigh and 4th Sts., Philadelphia, Pa.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Proportioneer, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Proportioneers, Inc., 9 Codding St., Providence, R. I. (Carbo-Feeders).

FEEDERS, ROTARY
Chain Belt Co., Milwaukee, Wis.
Fuller Co., Catasauqua, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

FEED WATER FILTERS
American Water Softener Co., Lehigh Ave. and 4th St., Philadelphia, Pa.
Graver Tank & Mfg. Co., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

FEED WATER HEATERS
Graver Tank & Mfg. Co., East Chicago, Ind.
Worthington Pump & Mach. Corp., Harrison, N. J.

FEED WATER TESTING OUTFITS
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
La Motte Chemical Prod. Co., McCormick Bldg., Baltimore, Md.
W. A. Taylor & Co., Inc., 872 Linden Ave., Baltimore, Md.

FEED WATER TREATMENT
American Water Softener Co., Lehigh Ave. and 4th St., Philadelphia, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

FENCING (IRON PICKET AND CHAIN LINK WIRE)
Pittsburgh Steel Co., Grant Bldg., Pittsburgh, Pa.

FERRIC CHLORIDE, LIQUID AND ANHYDROUS
Electro Bleaching Gas Co., 9 E. 41st St., New York City.
Great Western Electro Chemical Co., 9 Main St., San Francisco, Calif.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa. (Liquid)

FERRIC CHLORIDE FEEDERS
American Water Softener Co., Lehigh & 4th St., Philadelphia, Pa.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Omega Machine Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.

FERRIC SULFATE
Activated Alum Corp., 80 Broad St., New York City.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Monsanto Chem. Co., St. Louis, Mo.

FERRIC SULPHATE FEEDERS
American Water Softener Co., Lehigh and 4th Sts., Philadelphia, Pa.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

FERROUS SULPHATE
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.

FILTER-AIDS
Johns-Manville, 22 E. 40th St., New York City. (Celite.)
L. A. Salomon & Bro., 216 Pearl St., New York City.

FILTER CLEANING PROCESS
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., 230 Park Ave., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

FILTERING EQUIPMENT
American Water Softener Co., Lehigh & 4th St., Philadelphia, Pa.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Filtration Equipment Co., 10 E. 40th St., New York City.
Graver Tank & Mfg. Co., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

FILTER PLATES
Carborundum Co., Niagara Falls, N. Y.
Norton Co., Worcester, Mass.

FILTER RATE CONTROLLERS AND GAGES
(See Rate Controllers.)

FILTERS AND WATER SOFTENING PLANTS
American Water Softener Co., Lehigh Ave. and 4th St., Philadelphia, Pa.
Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

FILTERS, GRAVITY & PRESSURE
American Water Softener Co., Lehigh & 4th St., Philadelphia, Pa.
Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Roberts Filter Mfg. Co., Darby, Pa.

FILTERS, VACUUM
Filtration Equipment Corp., 10 E. 40th St., New York City.
Oliver United Filters, Inc., 33 W. 42nd St., New York City.

FILTER UNDERDRAINS (PIPE & PLATES)
American Water Softener Co., Lehigh & 4th Sts., Philadelphia, Pa.
Carborundum Co., Niagara Falls, N. Y.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
McWane Cast Iron Pipe Co., Birmingham, Ala.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Norton Co., Worcester, Mass.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

FILTRATION PLANT EQUIPMENT
American Water Softener Co., Lehigh Ave. and 4th St., Philadelphia, Pa.
Builders Iron Foundry, 9 Coddington St., Providence, R. I.
Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

FILTER SAND
(See also Anthrafilt.)
American Water Softener Co., Lehigh & 4th Sts., Philadelphia, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

FITTINGS, PIPE, SOLDER TYPE
American Brass Co., Waterbury, Conn.
American Radiator Co., 40 W. 40th St., New York City.
Chase Brass & Copper Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Farnan Brass Works Co., P. O. Box 6147, Cleveland, Ohio.
Mueller Brass Co., Streamline Pipe and Fittings Div., Port Huron, Mich.

FITTINGS, TEES, ELLS, ETC.
American Rolling Mill Co., Middletown, Ohio.
Builders Iron Foundry, 9 Coddington St., Providence, R. I.
Chase Brass & Copper Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
S. R. Dresser Mfg. Co., Bradford, Pa.
Lynchburg Foundry Co., Lynchburg, Va.

FITTINGS, UNDERGROUND SERVICE
American Brass Co., Waterbury, Conn.
Chase Brass & Copper Co., Inc., Waterbury, Conn.
S. R. Dresser Mfg. Co., Bradford, Pa.
Lynchburg Foundry Co., Lynchburg, Va.
McWane Cast Iron Pipe Co., Birmingham, Ala.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
Trohn's Supplies, Inc., Mamaroneck, N. Y.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

FLASH MIXERS
Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Vogt Mfg. Co., Louisville, Ky.

FLEXIBLE JOINTS
(See Joints, Flexible Pipe.)

FLOATING COVERS
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

FLOCCULATING EQUIPMENT
American Water Softener Co., Lehigh & 4th Sts., Philadelphia, Pa.
American Well Works, Inc., Aurora, Ill.
Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.

FLOOR GRATING
Arrowhead Iron Wks., 421 W. 5th St., Kansas City, Mo.

FLOOR STANDS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Western Gas Div., Koppers Co., Ft. Wayne, Ind.
R. D. Wood Co., Philadelphia, Pa.

FLOW RECORDERS
Builders Iron Foundry, 9 Codding St., Providence, R. I.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Simplex Valve & Meter Co., Philadelphia, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.

FLOW REGULATORS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Modern Iron Works, Quincy, Ill.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

FLUMES, IRON & STEEL
Armco Culvert Mfrs. Assn., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Lancaster Iron Works, Inc., 122 E. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

FOOT VALVE WITH STRAINER
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Edson Corp., 49 D. St., So. Boston, Mass.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
R. D. Wood, Philadelphia, Pa.

FORMS & GASKETS FOR PIPE JOINTS
Johns-Manville, 22 E. 40th St., New York City.
L. A. Weston, Adams, Mass.

FORMS, CONCRETE
Blaw-Knox Co., Pittsburgh, Pa.

FURNACES, MELTING, POURING LADLES, POTS, ETC.
Atlas Mineral Products, Mertztown, Pa.
Mueller Co., Decatur, Ill.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

GAGES, SURFACE, RESERVOIR AND SPECIAL WATER WORKS
American Water Softener Co., Lehigh Ave. and 4th St., Philadelphia, Pa.
Builders Iron Foundry, 9 Coddington St., Providence, R. I.

GARBAGE DISPOSAL APPARATUS
Chain Belt Co., Milwaukee, Wis.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Koppers Co., Engrg. & Constr. Div., Pittsburgh, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Nichols Engr. & Research Corp., 40 Wall St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

GAS DIFFUSERS
Carborundum Co., Niagara Falls, N. Y.
Dorr Co., 570 Lexington Ave., New York City.
Norton Co., Worcester, Mass.
Vogt Mfg. Co., Louisville, Ky.

GAS ENGINES
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Worthington Pump & Mach. Corp., Harrison, N. J.

GAS FIRED EQUIPMENT, RADIATORS, HEATERS, STORAGE HEATERS, AIR CONDITIONERS, ETC.
American Gas Prod. Corp., 40 W. 40th St., New York City.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Mueller Co., Decatur, Ill.

GAS HOLDERS
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Western Gas Div., Koppers Co., Ft. Wayne, Ind.

GAS PRODUCERS, AUTOMATIC
Cooper-Bessemer Corp., Mount Vernon, Ohio.
Koppers Co., Engrg. & Constr. Div., Pittsburgh, Pa.
R. D. Wood Co., Philadelphia, Pa.

GATES, DRAINAGE
Armco Culvert Mfrs. Assn., Middletown, Ohio.

GATES, IRON PICKET & CHAIN LINK WIRE
Pittsburgh Steel Co., Grant Bldg., Pittsburgh, Pa.

GATES, ROTARY DISCHARGE
Fuller Co., Catasauqua, Pa.

GATES, SHEAR
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fitting Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Western Gas Div., Koppers Co., Ft. Wayne, Ind.

GATES, SLUICE
Armco Culvert Mfrs. Assn., Middletown, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
Western Gas Div., Koppers Co., Ft. Wayne, Ind.

GATE VALVE HOUSING
Ludlow Valve Mfg. Co., Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.

GATE VALVES
(See Valves, Gate.)

GAUGES, LIQUID LEVEL, PRESSURE RECORDING
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry, 9 Codding St., Providence, R. I.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.

GEARS, SPEED REDUCING
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Moore Steam Turbine Corp., Wellsville, N. Y.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.

GENERATORS, ACETYLENE
Victor Equipment Co., 844 Folsom St., San Francisco, Calif.

GENERATORS, SETS, ELECTRIC & DIESEL ENGINES
Cooper-Bessemer Corp., Mt. Vernon, Ohio.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
Worthington Pump Corp., Harrison, N. J.

GOOSENECKS
Farnan Brass Works Co., P. O. Box 6147, Cleveland, Ohio.
Mueller Brass Co., Streamline Pipe & Fittings Div., Fort Huron, Mich.
Mueller Co., Decatur, Ill.
Trohn's Supplies, Inc., Mamaroneck, N. Y.

GRATINGS, FLOORINGS
Arrowhead Iron Wks., Kansas City, Mo.

GRAY IRON CASTINGS
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Corp., 122 S. Michigan Ave., Chicago, Ill.
Chain Belt Co., Milwaukee, Wis.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Lynchburg Foundry Co., Lynchburg, Va.
M. & H. Valve & Fittings Co., Anniston, Ala.
McWane Cast Iron Pipe Co., Birmingham, Ala.
So. Bend Foundry, So. Bend, Ind.
U. S. Pipe & Foundry Co., Burlington, N. J.
Western Gas Div., Koppers Co., Ft. Wayne, Ind.
R. D. Wood Co., Philadelphia, Pa.

GREEN SAND (Zeolite)
Graver Tank & Mfg. Co., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

GRINDERS
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Norton Co., Worcester, Mass.

GRIT CHAMBER EQUIPMENT
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

HEATERS, FEED WATER
Worthington Pump & Machy. Corp., Harrison, N. J.

HOSE, STEAM, AIR, WATER, SUCTION
American Brass Co., Waterbury, Conn.
Edson Corp., 49 D St., So. Boston, Mass.

HYDRANT PROTECTORS
Edson Corp., 49 D. St., So. Boston, Mass.

HYDRANT PUMPS
(See Pumps, Hydrant.)

HYDRANTS (FIRE)
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Western Gas Div., Koppers Co., Ft. Wayne, Ind.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Decatur, Ill.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

HYDRATED LIME
Limestone Prod. Corp. of Amer., Newton, N. J.

HYDRAULIC VALVE CONTROLS
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., Philadelphia, Pa.
R. D. Wood Co., Philadelphia, Pa.

HYDRAULICALLY OPERATED GATE VALVES
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.

HYDROGEN ION EQUIPMENT
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
La Motte Chem. Co., Baltimore, Md.
Permutit Co., 330 W. 42nd St., New York City.
Precision Scientific Co., 1750 N. Springfield Ave., Chicago, Ill.
W. A. Taylor & Co., Inc., 872 Linden Ave., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilkins-Anderson Co., 111 N. Canal St., Chicago, Ill.

HYPO-CHLORINATORS
American Water Softener Co., Lehigh & 4th St., Philadelphia, Pa.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Pardee Engineering Co., 3915 29th St., Long Island City, N. Y.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Newark, N. J.

INCINERATORS
Dorr Co., Inc., 570 Lexington Ave., New York City.
Koppers Co., Engrg. & Constr. Div., Pittsburgh, Pa.
Nichols Engr., 40 Wall St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

INDICATORS, CHEMICAL
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
La Motte Chem. Prod. Co., Baltimore, Md.
W. A. Taylor & Co., 872 Linden Ave., Baltimore, Md.
Wilkins-Anderson Co., 111 N. Canal St., Chicago, Ill.

INDICATOR POSTS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
R. D. Wood Co., Philadelphia, Pa.

INDICATORS, LARGE DIAL, ILLUMINATED
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Builders Iron Foundry, 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

INSTRUMENTS, FLOW RECORDING, TROUBLE FINDING
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

INSULATION
Ford Meter Box Co., Wabash, Ind. (Water Meter).
Johns-Manville, 22 E. 40th St., New York City.

IRON & MANGANESE REMOVAL PLANTS
American Water Softener Co., Lehigh Ave. and 4th St., Philadelphia, Pa.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.

IRON SALTS IN SEWAGE TREATMENT
Activated Alum Corp., 80 Broad St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Gt. Western Electro-Chemical Co., 9 Main St., San Francisco, Calif.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.

IRON SULPHATE
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.

JOINTING COMPOUND
Atlas Mineral Prod. Co., Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Leadite Co., Philadelphia, Pa.
Mueller Co., Decatur, Ill.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

JOINTS, EXPANSION—PIPE
Amer. Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Corp., 122 S. Michigan Ave., Chicago, Ill.
S. R. Dresser Mfg. Co., Bradford, Pa.
Lock-Joint Pipe Co., Ampere, N. J.
McWane Cast Iron Pipe Co., Birmingham, Ala.
Servicised Prod. Co., 6051 W. 65th St., Chicago, Ill.

JOINTS, FILLER
Inertol Co., 401 Broadway, New York City.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

JOINTS, FLEXIBLE PIPE
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
S. R. Dresser Mfg. Co., Bradford, Pa.

Lynchburg Foundry Co., Lynchburg, Va.
McWane Cast Iron Pipe Co., Birmingham, Ala.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
R. D. Wood Co., Philadelphia, Pa.

JOINTS, MECHANICAL

American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
S. R. Dresser Mfg. Co., Bradford, Pa.
Lynchburg Foundry Co., Lynchburg, Va.
McWane Cast Iron Pipe Co., Birmingham, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
Weston's Gaskets & Forms, Adams, Mass.
R. D. Wood Co., Philadelphia, Pa.

JUTE, BRAIDED AND TWISTED

Atlas Mineral Prod. Co., Mertztown, Pa.
Johns-Manville, 22 E. 40th St., New York City.
Tar and Chem. Div., Koppers Co., Pittsburgh, Pa.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

LABORATORY APPARATUS

Carborundum Co., Niagara Falls, N. Y.
Corning Glass Works, Corning, N. Y.
Heilige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
National Aluminate Corp., 6216 W. 66th Pl., Chicago, Ill.
Norton Co., Worcester, Mass.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Phipps & Bird, 915 E. Cary St., Richmond, Va.
Precision Scientific Co., 1750 N. Springfield Ave., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan, Inc., Newark, N. J.
Wilkins - Anderson Co., 111 N. Canal St., Chicago, Ill.

LABORATORY WARE

Carborundum Co., Niagara Falls, N. Y.
Corning Glass Works, Corning, N. Y.
La Motte Chem. Prod. Co., McCormick Bldg., Baltimore, Md.
Norton Co., Worcester, Mass.
Phipps & Bird, 915 E. Cary St., Richmond, Va.
Precision Scientific Co., 1750 N. Springfield Ave., Chicago, Ill.
Wilkins - Anderson Co., 111 N. Canal St., Chicago, Ill.

LEADITE

The Leadite Co., Girard Trust Co. Bldg., Philadelphia, Pa.

LINERS, ASPHALT SEWER

Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

LIQUID CHLORINE

(See Chlorine, Liquid.)

MACHINES, DRILLING

Mueller Co., Decatur, Ill.

MANOMETERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

MASTER METERS

Badger Meter Mfg. Co., Milwaukee, Wis.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Simplex Valve & Meter Co., Philadelphia, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.

METALS—CORROSION RESISTING

Amer. Brass Co., Waterbury, Conn.
Chase Brass & Copper Co., Waterbury, Conn.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.

METER ACCESSORIES, BOXES, HOUSING, ETC.

Badger Meter Co., Milwaukee, Wis.
Ford Meter Box Co., Wabash, Ind.
Modern Iron Works, Quincy, Ill.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METER COUPLINGS & YOKES

Badger Meter Mfg. Co., Milwaukee, Wisc.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
S. R. Dresser Mfg. Co., Bradford, Pa.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METERS, GAS

Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Precision Scientific Co., 1750 N. Springfield Ave., Chicago, Ill.

METERS, PITOT

Simplex Valve & Meter Co., 68th & Upham Sts., Philadelphia, Pa.

METER TESTING EQUIPMENT

Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METERS, VENTURI

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

METERS, WATER AND SEWAGE

Badger Meter Mfg. Co., Milwaukee, Wis.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron & Foundry Co., Providence, R. I.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.
Union Water Meter Co., Worcester, Mass.
Worthington-Gamon Meter Co., Harrison, N. J.

METER WASHERS

Mabbs Hydraulic Packing Co., 431 S. Dearborn St., Chicago, Ill.

MIXERS, CHEMICAL

American Water Softener Co., Lehigh and 4th Sts., Philadelphia, Pa.
Chicago Pump Co., 2349 Wolfrom St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., East Chicago, Ind.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Louisville, Ky.

MIXERS, CONCRETE

(See Concrete Mixers)

MIXING BASIN EQUIPMENT

American Water Softener Co., Lehigh and 4th Sts., Philadelphia, Pa.
Carborundum Co., Niagara Falls, N. Y.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Louisville, Ky.

MOTOR STARTERS

Clark Controller Co., 1146 E. 152nd St., Cleveland, O.

NIPPLES, PIPE

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
S. R. Dresser Mfg. Co., Bradford, Pa.
Mueller Brass Co., Port Huron, Mich.

NOZZLES, FLOW

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Chain Belt Co., Milwaukee, Wis.
Pacific Flush Tank Co., 4241 N. Ravenswood Ave., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

NOZZLES, SPRAY

Chain Belt Co., Milwaukee, Wis.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Mueller Brass Co., Streamline Pipe & Fittings Div., Port Huron, Mich.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

ODOR & CARBON EVALUATION AIDS

Cliffs Dow Chemical Co., Marquette, Mich.
Darco Corp., 60 E. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

OPERATING TABLES

American Water Softener Co., Lehigh and 4th Sts., Philadelphia, Pa.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

ORIFICES

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

PACKING

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City.

PACKING, RAWHIDE

Chicago Rawhide Mfg. Co., 1283 Elston Ave., Chicago, Ill.
Mabbs Hydraulic Packing Co., 431 S. Dearborn St., Chicago, Ill.

PAINT, ACID RESISTING

Atlas Mineral Prod. Co., Mertztown, Pa.
Barrett Co., 40 Rector St., New York City.
Ebony Paint Mfg. Co., 2925 E. 18th St., Kansas City, Mo.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Inertol Co., Inc., 401 Broadway, New York City.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh, Pa. (15)
Wailes Dove-Hermiston Corp., 17 Battery Pl., New York City.

PAVEMENT BREAKERS

Worthington Pump & Mach. Corp., Harrison, N. J.

PENSTOCKS

Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Graver Tank & Mfg. Co., East Chicago, Ind.
Lancaster Iron Works, Inc., 122 E. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

pH EQUIPMENT

American Water Softener Co., Lehigh and 4th Sts., Philadelphia, Pa.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Heilige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
La Motte Chem. Prod. Co., Baltimore, Md.
National Aluminate Corp., 6216 W. 66th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Precision Scientific Co., 1750 N. Springfield Ave., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., Inc., 872 Linden Ave., Baltimore, Md.
Wallace & Tiernan, Inc., Newark, N. J. (automatic)
Wilkins - Anderson Co., 111 N. Canal St., Chicago, Ill.

PILING, CORRUGATED STEEL SHEET

Corrugated Steel Sheet Piling Corp., 228 N. La Salle St., Chicago, Ill.

PIPE AND TANK COATINGS

The Barrett Co., 40 Rector St., New York City.
Ebony Paint Mfg. Co., 2925 E. 18th St., Kansas City, Mo.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Inertol Co., Inc., 401 Broadway, New York City.
Koppers Co., Tar & Chemical Div., Pittsburgh, Pa.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Wailes Dove-Hermiston Corp., 17 Battery Pl., New York City.

PIPE, ACID PROOF, FOR CHEMICAL LINES

American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Chase Brass & Copper Co., Waterbury, Conn.
Corning Glass Works, Corning, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Lynchburg Foundry Co., Lynchburg, Va.
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE, ASBESTOS-CEMENT

Johns-Manville Co., 22 E. 40th St., New York City.

PIPE, BRASS AND COPPER

American Brass Co., Waterbury, Conn.
Chase Brass & Copper Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Brass Co., Streamline Pipe and Fittings Div., Port Huron, Mich.

PIPE, CAST IRON

American Cast Iron Pipe Co., Birmingham, Ala.
American Radiator Co., 40 W. 40th St., New York City.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Lynchburg Foundry Co., Lynchburg Va.
McWane Cast Iron Pipe Co., Birmingham, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
R. D. Wood Co., Philadelphia, Pa.

PIPE, CAST IRON SERVICE, SMALL DIAMETER

American Cast Iron Pipe Co., Birmingham, Ala.
American Radiator Co., 40 W. 40th St., New York, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
McWane Cast Iron Pipe Co., Birmingham, Ala.

PIPE, CEMENT LINED

American Cast Iron Pipe Co., Birmingham, Ala.
Lynchburg Foundry Co., Lynchburg, Va.
McWane Cast Iron Pipe Co., Birmingham, Ala.
United States Pipe & Foundry Co., Burlington, N. J.
R. D. Wood Co., Philadelphia, Pa.

PIPE, COMMERCIAL O. D. WITH THREADED JOINTS

Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
McWane Cast Iron Pipe Co., Birmingham, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE, CONCRETE, PRESSURE
Lockjoint Pipe Co., Ampere, N. J.
Portland Cement Association, 33 W. Grand Ave., Chicago, Ill.

PIPE CONNECTIONS
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
S. R. Dresser Mfg. Co., Bradford, Pa.
Lynchburg Foundry Co., Lynchburg, Va.
McWane Cast Iron Pipe Co., Birmingham, Ala.
M. B. Skinner Co., South Bend, Ind.
R. D. Wood Co., Philadelphia, Pa.

PIPE, COPPER
American Brass Co., Waterbury, Conn.
American Radiator Co., 40 W. 40th St., New York City.
Chase Brass & Copper Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Farnan Brass Works Co., P. O. Box 6147, Cleveland, Ohio.
Mueller Brass Co., Streamline Pipe & Fitting Div., Port Huron, Mich.
Mueller Co., Decatur, Ill.

PIPE, CORRUGATED
Armco Culvert Mfrs. Assn., Middletown, Ohio.
Mueller Brass Co., Streamline Pipe and Fittings Div., Port Huron, Mich.

PIPE, CULVERT
Armco Culvert Mfrs. Assn., Middletown, Ohio.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE CUTTING MACHINES
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

PIPE ENAMELS, PROTECTIVE—COAL TAR
Barrett Co., 40 Rector St., New York City.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Wailes Dove-Hermiston Corp., 17 Battery Pl., New York City.

PIPE, FELT WRAPPING
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.

PIPE FITTINGS
American Cast Iron Pipe Co., Birmingham, Ala.
American Rolling Mill Co., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
S. R. Dresser Mfg. Co., Bradford, Pa.
Lynchburg Foundry Co., Lynchburg, Va.
M. & H. Valve & Fitting Co., Anniston, Ala.
McWane Cast Iron Pipe Co., Birmingham, Ala.
Mueller Brass Co., Streamline Pipe and Fittings Div., Port Huron, Mich.
Mueller Co., Decatur, Ill.
M. B. Skinner Co., South Bend, Ind.
U. S. Pipe & Foundry Co., Burlington, N. J.
R. D. Wood Co., Philadelphia, Pa.

PIPE, GLASS
Corning Glass Works, Corning, N.Y.

PIPE JOINT COMPOUNDS
Atlas Mineral Products, Mertztown, Pa.
The Barrett Co., 40 Rector St., New York City.
Leadite Co., Philadelphia, Pa.
Modern Iron Works, Quincy, Ill.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh, Pa. (15)
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

PIPE JOINTS, MECHANICAL
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
S. R. Dresser Mfg. Co., Bradford, Pa.

PIPE JOINT TOOLS
Allan J. Coleman, 120 W. Illinois St., Chicago, Ill.
Mueller Co., Decatur, Ill.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

PIPE, LEAD LINED
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

PIPE LOCATORS
Water Leak Detector Co., 155 N. Third St., Columbus, Ohio.

PIPE, SEWER
American Cast Iron Pipe Co., Birmingham, Ala.
Armco Culvert Mfrs. Assn., Middletown, Ohio.
Cast Iron Pipe Research Corp., 122 S. Michigan Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., Ampere, N. J.
Lynchburg Foundry Co., Lynchburg, Va.
McWane Cast Iron Pipe Co., Birmingham, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE, STEEL
American Rolling Mill Co., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Graver Tank & Mfg. Co., East Chicago, Ind.
Western Gas Div., Koppers Co., Ft. Wayne, Ind.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Lancaster Iron Works, Inc., 122 E. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

PIPE, SUBAQUEOUS
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Lock Joint Pipe Co., Ampere, N. J.

PIPE TAPPING MACHINES
Mueller Co., Decatur, Ill.

PIPE THAWERS
(See Thawers, Pipe)

PIPE. WELDED STEEL
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

PIPE, WRAPPING
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.

PITOT TUBES
Builders Iron Foundry Co., Providence, R. I.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

PLANTS, MUNICIPAL FILTRATION
American Water Softener Co., Lehigh and 4th Sts., Philadelphia, Pa.
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Graver Tank & Mfg. Co., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Roberts Filter Mfg. Co., Darby, Pa.

PLUGS, TEST
(See Test Plugs)

PNEUMATIC CONVEYORS FOR WATER AND SEWAGE TREATMENT
Dracco Corp., Cleveland, Ohio.
Fuller Co., Catasauqua, Pa.

POROUS TUBES AND PLATES
Carborundum Co., Niagara Falls, N. Y.
Norton Co., Worcester, Mass.

POTENTIOMETERS
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

POURING GATES
Allan J. Coleman, 120 W. Illinois St., Chicago, Ill.

POWER TRANSMISSION MACHINERY
Chain Belt Co., Milwaukee, Wis.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Reeves Pulley Co., Columbus, Ind.
Worthington Pump & Machy. Corp., Harrison, N. J.

PRESSURE REGULATORS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Co., Decatur, Ill.

PROPORTIONING EQUIPMENT (CHEMICAL)
American Water Softener Co., Lehigh and 4th Sts., Philadelphia, Pa.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., East Chicago, Ind.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.

PROTECTION COURSE FOR WATERPROOFING
Johns-Manville, 22 E. 40th St., New York City.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

PUMP MOTOR STARTERS
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

PUMPS, ACID-HANDLING
American Well Works, Aurora, Ill.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumps, Inc., Hamilton, Ohio.
Oliver United Filters, Inc., 33 W. 42nd St., New York City (chemical).
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Victor Equipment Co., 1010 East 62nd St., Los Angeles, Calif.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, AIR LIFT
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, BOILER FEED
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumps, Inc., Hamilton, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Vogt Brothers Mfg. Co., Louisville, Ky.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, CELLAR DRAINER
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Victor Equipment Co., 1010 E. 62nd St., Los Angeles, Calif.

PUMPS, CENTRIFUGAL
American Well Works, Inc., Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumps, Inc., Hamilton, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Layne & Bowler, Inc., Memphis, Tenn.
Oliver United Filters, Inc., 33 W. 42nd St., New York City.
Victor Equipment Co., 1010 E. 62nd St., Los Angeles, Calif.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, CENTRIFUGAL AND MULTI-STAGE HIGH LIFT
American Well Works, Inc., Aurora, Ill.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumps, Inc., Hamilton, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Layne & Bowler, Inc., Memphis, Tenn.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, CHEMICAL, PROPORTIONING
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
Oliver United Filters, Inc., 33 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, CONDENSATION
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumping Machinery Co., 3431 W. 48th Pl., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, DEEP WELL
American Well Works, Inc., Aurora, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Layne & Bowler, Inc., Memphis, Tenn.
Pomona Pump Co., Pomona, Calif.
Victor Equipment Co., 1010 E. 62nd St., Los Angeles, Calif.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, DIAPHRAGM
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Edson Corp., 49 D St., South Boston, Mass.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.

PUMPS, DRAINAGE
American Well Works, Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Allan J. Coleman, 120 W. Illinois St., Chicago, Ill.
Economy Pumps, Inc., Hamilton, Ohio.
Kimball-Krogh Pump Div., Victor Equipment Co., 1010 East 62nd St., Los Angeles, Calif.
Pomona Pump Co., Pomona, Calif.
S. Morgan Smith Co., York, Pa.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, HYDRANT
Edson Corp., 49 D St., South Boston, Mass.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.

PUMPS, NON-CLOG
American Well Works, Inc., Aurora, Ill.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumps, Inc., Hamilton, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Victor Equipment Co., 1010 E. 62nd St., Los Angeles, Calif.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, PORTABLE
Economy Pumps, Inc., Hamilton, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, POWER
Edson Corp., 49 D. St., South Boston, Mass.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Worthington Pump & Mach. Corp., Harrison, N. J.

PUMPS, PROPELLER TYPE
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumps, Inc., Hamilton, Ohio.
Kimball-Krogh Pump Div., Victor Equipment Co., 1010 E. 62nd St., Los Angeles, Calif.
Pomona Pump Co., Pomona, Calif.
S. Morgan Smith Co., York, Pa.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, ROTARY
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, SCREW FEED CENTRIFUGAL
American Well Works, Inc., Aurora, Ill.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, SEWAGE
American Well Works, Inc., Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Economy Pumps, Inc., Hamilton, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Victor Equipment Co., 1010 E. 62nd St., Los Angeles, Calif.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, SLUDGE
American Well Works, Inc., Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Economy Pumps, Inc., Hamilton, Ohio.
Fuller Co., Catasauqua, Pa.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, SUCTION AND FORCE
Allan J. Coleman, 120 W. Illinois St., Chicago, Ill.
Edson Corp., 49 D St., South Boston, Mass.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, SUMP
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumps, Inc., Hamilton, Ohio.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Pomona Pump Co., Pomona, Calif.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, TURBINE
American Well Works, Inc., Aurora, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Layne & Bowler, Inc., Memphis, Tenn.
Pomona Pump Co., Pomona, Calif.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, VACUUM
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumps, Inc., Hamilton, Ohio.
Fuller Co., Catasauqua, Pa.
Oliver United Filters, Inc., 33 W. 42nd St., New York City.
Worthington Pump & Machy. Corp., Harrison, N. J.

RATE OF FLOW CONTROLLERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

REAMERS
Mueller Co., Decatur, Ill.

RECARBONATORS
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

RECORDERS, GAS DENSITY
Permutit Co., 330 W. 42nd St., New York City.

RECORDERS, pH.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

RECORDING INSTRUMENTS
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry, 9 Coddington St., Providence, R. I.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

RECUPERATOR
Carborundum Co., Perth Amboy, N. J.

REFRACTORIES
Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.
Norton Co., Worcester, Mass.

REFRACTORY CEMENTS
Carborundum Co., Niagara Falls, N. Y.
Johns-Manville, 22 E. 40th St., New York City.
Norton Co., Worcester, Mass.

REGULATORS, PRESSURE AND VACUUM
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

REGULATORS, PRESSURE, ACETYLENE GAS
Union Water Meter Co., Worcester, Mass.
Victor Equipment Co., 840 Folsom St., San Francisco.

REGULATORS, SEWER
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

REGULATORS, WATER AND GAS
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

RESERVOIRS
(See Standpipes and Tanks)

RETAINING WALLS
Armco Culvert Mfrs. Assoc., Middletown, Ohio.
Corrugated Steel Sheet Piling Corp., 228 N. La Salle St., Chicago, Ill.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.

RINGS, ANTI-ROOT
A-B-C Manufacturing Co., Quincy, Ill.

ROBOT FILTER AND SOFTENER OPERATORS
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

ROCK DRILLS
Allan J. Coleman, 120 W. Illinois St., Chicago, Ill.
Worthington Pump & Machinery Corp., Harrison, N. J.

ROOFING
American Brass Co., Waterbury, Conn.
Barrett Co., The, 40 Rector St., New York City.
Chase Brass & Copper Co., Waterbury, Conn.
Johns-Manville, 22 E. 40th St., New York City.
Koppers Co., Tar & Chem. Div., Pittsburgh, Pa.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.

SADDLES, PIPE
S. R. Dresser Mfg. Co., Bradford, Pa.
M. B. Skinner Co., South Bend, Ind.

SAMPLERS AND SAMPLING TABLES
American Water Softener Co., Lehigh and 4th Sts., Philadelphia, Pa.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.

SAND AND GRAVEL PLANTS
Chain Belt Co., Milwaukee, Wisc.
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher and Pulverizer Co., Dept. S, 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

SAND EXPANSION INDICATORS
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

SAND FILTRATION
Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

SCREENS, INTAKE
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

SCREENS, SAND, GRAVEL AND STONE
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

SCREENS, SEWAGE
American Well Works, Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Filtration Equipment Corp., 10 E. 40th St., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

SCREENS, SPECIAL
Jeffrey Mfg. Co., Columbus, Ohio.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Koppers, Western Gas Div., Ft. Wayne, Ind.

SCREENS, WATER WELL
Layne & Bowler, Inc., Memphis, Tenn.

SELF-CAULKING PIPE JOINT COMPOUNDS
Atlas Mineral Prod., Mertztown, Pa.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

SEWAGE EJECTORS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumps, Inc., Hamilton, Ohio.

SEWAGE SAMPLERS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

SEWAGE SCREENING GRINDERS
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Royer Foundry & Mach. Co., Kingston, Pa.

SEWAGE SLUDGE INCINERATOR
Dorr Co., 570 Lexington Ave., New York City.
Nichols Engineering & Research Corp., 40 Wall St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

SEWAGE TREATMENT EQUIPMENT
American Centrifugal Corp., 115 Broadway, New York City.
American Colloid Co., 363 W. Superior St., Chicago, Ill.
American Water Softener Co., Lehigh and 4th Sts., Philadelphia, Pa.
American Well Works, Inc., Aurora, Ill.
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Economy Pumps, Inc., Hamilton, Ohio.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Filtration Equipment Corp., 10 E. 40th St., New York City.
Graver Tank & Mfg. Co., East Chicago, Ind.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lancaster Iron Works, 122 E. 42nd St., New York City.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
Vogt Mfg. Co., Louisville, Ky.
Wallace & Tiernan Co., Inc., Newark, N. J.

SEWER MAIN CLEANERS
Champion Corp., Hammond, Ind.
Allan J. Coleman, 120 W. Illinois St., Chicago, Ill.

SEWER PIPE JOINTS
A-B-C Manufacturing Co., Quincy, Ill. (Root Proof)
Atlas Mineral Prod. Co., Mertztown, Pa.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.
L. A. Weston, Adams, Mass.

SEWER RODS
Champion Corp., Hammond, Ind.
Allan J. Coleman, 120 W. Illinois St., Chicago, Ill.

SIGHT GLASSES
Corning Glass Works, Corning, N. Y. (Pyrex Brand)

SIGNALS, BIN
Fuller Co., Catasauqua, Pa.

SIPHONS
Armco Culvert Mfrs. Assoc., Middletown, Ohio.
Modern Iron Works, Quincy, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

SLEEVES, PIPE REPAIR
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
S. R. Dresser Mfg. Co., Bradford, Pa.
M. & H. Valve & Fittings Co., Anniston, Pa.
Mueller Co., Chattanooga, Tenn.
McWane Cast Iron Pipe Co., Birmingham, Ala.
Rensselaer Valve Co., Troy, N. Y.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

SLEEVES, TAPPING (VALVE)

Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
Vogt Mfg. Co., Louisville, Ky.

SLUDGE COLLECTORS

American Well Works, Inc., Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Filtration Equipment Corp., 10 E. 40th St., New York City.
Graver Tank & Mfg. Co., East Chicago, Ind.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

SLUDGE DEWATERING

American Centrifugal Corp., 115 Broadway, New York City.
Bowen Research Corp., Garwood, N. J.
Filtration Equipment Corp., 10 E. 40th St., New York City.

SLUDGE DISINTEGRATORS

Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Oliver United Filters, Inc., 33 W. 42nd St., New York City.
Royer Foundry & Mach. Co., 158 Pringle St., Kingston, Pa.

SLUDGE FILTERS

Filtration Equipment Corp., 10 E. 40th St., New York City.
Oliver United Filters Co., 33 W. 42nd St., New York City.

SLUDGE PUMPS

American Well Works, Inc., Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.

SLUDGE TESTING (pH AND CHLORINE)

Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
La Motte Chem. Prod. Co., McCormick Bldg., Baltimore, Md.
W. A. Taylor & Co., Inc., 872 Linden Ave., Baltimore, Md.
Worthington Pump & Machy. Corp., Harrison, N. J.

SODA ASH

The Columbia Alkali Corp., Barberton, Ohio.
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Mathieson Alkali Works, 60 E. 42nd St., New York City.
Penn. Salt. Mfg. Co., Widener Bldg., Philadelphia, Pa.
Solvay Sales Corp., 40 Rector St., New York City.

SODIUM ALUMINATE

Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
National Aluminate Corp., 6216 W. 66th Pl., Chicago, Ill.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

SODIUM SILICATE

Philadelphia Quartz Co., Philadelphia, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

SODIUM HYPOCHLORITE

The Columbia Alkali Corp., Barberton, Ohio.
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Great Western Electro-Chemical Co., 9 Main St., San Francisco, Calif.
Mathieson Alkali Works, 60 E. 42nd St., New York City.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Monsanto Chemical Co., St. Louis, Mo.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

SOFTENERS AND PURIFIERS

American Water Softener Co., Lehigh Ave. at 4th St., Philadelphia, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

SPECIAL VESSELS

Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Allan J. Coleman, 120 W. Illinois St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.

SPEED REDUCERS, TRANSMISSION

Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Reeves Pulley Co., Columbus, Ind.

SPRAY DRYING EQUIPMENT

Bowen Research Corp., Garwood, N. J.

SPRINKLING FILTER PLANTS

Dorr Co., 570 Lexington Ave., New York City.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

STACKS

Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Lancaster Iron Works, Inc., 122 E. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

STACKS, FUME

Johns-Manville, 22 E. 40th St., New York City.

STANDPIPE AND TANKS

Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Graver Tank & Mfg. Co., East Chicago, Ind.
Lancaster Iron Works, Inc., 122 E. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

STEAM AND GAS PURIFIERS

Carborundum Co., Niagara Falls, N. Y.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.

STIRRERS (LABORATORY)

Dorr Co., 570 Lexington Ave., New York City.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Precision Scientific Co., 1750 N. Springfield Ave., Chicago, Ill.

STOKERS

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
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Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

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Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Lancaster Iron Works, Inc., 122 E. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

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Activated Alum Corp., 80 Broad St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.

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Graver Tank & Mfg. Co., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
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Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Faesy & Besthoff, Inc., 22 E. 42nd St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
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Wallace & Tiernan Co., Inc., Newark, N. J.

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Chain Belt Co., Milwaukee, Wis.
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Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., East Chicago, Ind.
Lancaster Iron Wks., 122 E. 42nd St., New York City.
Link Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

TANKS, SEPTIC

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Lancaster Iron Works, Inc., 122 E. 42nd St., New York City.

TANKS, STEEL

(See Tanks, Elevated Steel)

TAPPING MACHINES

Mueller Co., Decatur, Ill.

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Darco Corp., 60 E. 42nd St., New York City.
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Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., Inc., 230 Park Ave., New York City.
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Wallace & Tiernan Co., Inc., Newark, N. J.

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Dorr Co., Inc., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
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Engesser Electric Co., Watertown, N. Y.

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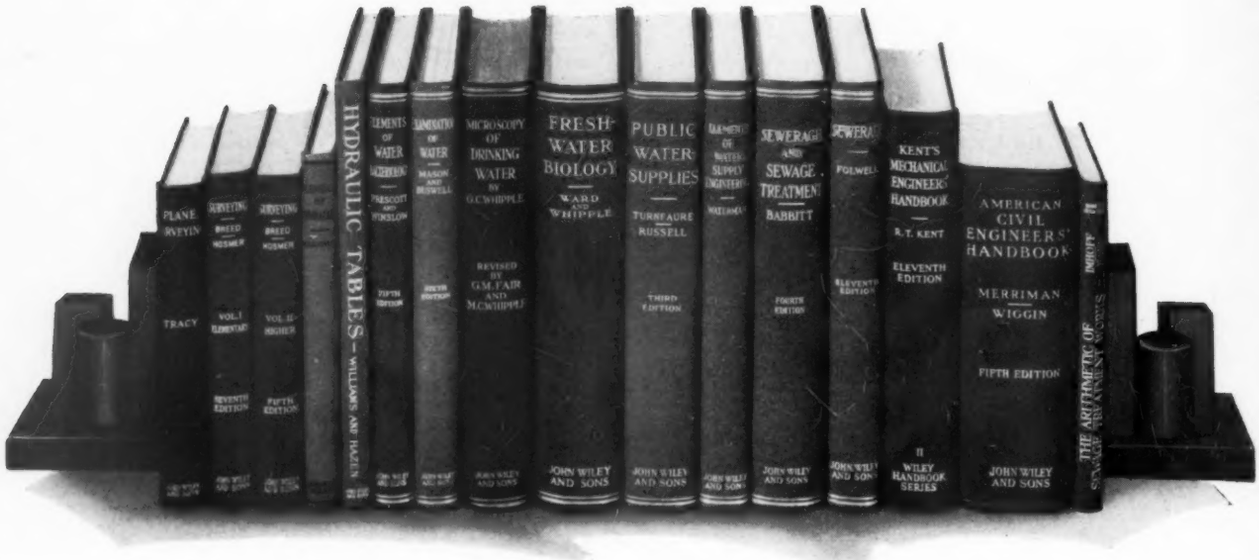

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INFORMATION ON WATER AND SEWAGE WORKS PROBLEMS* —WHERE TO FIND IT

By L. H. ENSLOW
Editor WATER WORKS AND SEWERAGE

The subject which has been assigned me is of a rather large order and will be dealt with only in part. I will content myself with stating where information of various sorts may be found.

It goes without saying that information required by water works men and sewage works operators is not concentrated in two or three books. The nearest approach to concentrated information for water works men is found in the manual published by the American Water Works Association—"Water Works Practice."

Regardless of the availability of published information, reference books, etc., it is well known that practical experience is essential in solving most water and sewage problems.

Reference Works. Text books, manuals, hand-books, journals, and catalogs are named in the attached list of recommended reference work for water sewage works men.

The list represents the majority opinions of operating men, managers, engineers and chemists. I was somewhat reticent about taking the sole responsibility of naming such a list and therefore called on men fully qualified to offer suggestions to make up a set of reference works.

I had not thought of catalogs put out by manufacturers as being of value beyond use in specifying and purchasing materials and equipment, but one of my collaborators who is Superintendent of Operations of a company operating a large number of plants states the following:

"I find that in my own work the most frequently consulted books are the catalogs of the manufacturers of water works materials and equipment. These catalogs are of constant use, not only in connection with the purchasing of the goods listed, but also due to the vast amount of information contained in them as to the available styles, weights, dimension, capacities, and many other features."

Small Works and Large Works. It had been my thought that I might make up a list of reference works which would cover the needs of managers and operators of small and medium sized works and another which would be more extensive for the larger works. A superintendent of a small works writes as follows, and I am forced to agree with him to a major degree.

"In my opinion, the small town superintendent should have just as complete knowledge of fundamentals as the large town superintendent and in fact would have problems coming to his personal attention which might require more detailed knowledge than would be the case with the superintendent of a large system who would delegate such work to various assistants."

Current Information. Current information is best obtained through the technical journals, trade papers, manufacturers' publications.

Attending meetings, listening to papers read and discussion of these, is of paramount value. Demonstrations such as those put on during meetings are extremely valuable and operations of this nature can not, as a rule, be found described in books. Operating papers in the journals and trade publications, however, frequently describe "operating kinks" of a great value.

Reprints and Bulletins. Manufacturers and Trade Associations frequently distribute information of value in the nature of reprinted articles, house-organs or bulletins. Ofttimes these are mailed out only upon request, or by sending in a coupon incorporated in an advertisement. It therefore pays to read the ads.

Such publications usually contain valuable information and often serve a very useful purpose. If they are not bulky these may be filed away or placed in a loose leaf binder under the heading of the subject matter, as for example, "Meters and Meter Maintenance," "Tanks and Standpipes," "Water Treatment," "Algae Control," etc., etc. If bulky, they may be torn apart and the most valuable parts filed for future reference. It is surprising how much worthwhile information and data can thus be accumulated in a readily available form and at practically no cost. Some men make a practice of tearing apart technical magazines and filing the desired contents under subject matter heading where the information will be more readily available thereafter.

Filing Schemes. I have found the following filing schemes practical, serviceable and inexpensive:

For the office, the old fashioned and inexpensive box letter-file, made of cardboard and wood, is very useful. The index is removed and the clippings, reprints, etc., covering a single "subject-head" are placed in envelopes or folders properly labeled and preserved in the box files. These boxes are properly labeled to show their subject matter contents and stored on end on a shelf as one would store a set of books. As the contents of a single box grows it may be necessary later to devote an entire box to a single subject head. "Water Treatment" for example will probably require a single box which may contain a folder on water softening, and others on coagulation, aeration, corrosion control, etc. One subject head can be broken down into as many sub-divisions as may appear desirable. I have one which contains 16 sub-divisions and this assists in prompt location of the desired information when needed.

Some people may prefer to use metal box files of the same size which are also available, but more expensive. Others may prefer a set of loose leaf binders, but I find the boxes are simpler, offer more protection to the filed sheets and keep the dust out.

Information such as conversion factors, data tables and formulae which are more frequently used may best be filed in a pocket-size loose leaf book. The paper can be reinforced with little gummed linen eyelets where the rings pass through and the sheet folded if need be to fit into the binder or it may be cut into parts and glued at its corners to both sides of a filler sheet of the binder. An index in the binder serves a useful purpose in that it facilitates location of the desired tables of data or conversion figures. For work in the field the pocket size loose-leaf book is almost indispensable. I have one fairly well filled with curves and data cut from magazines, journals, and booklets distributed by manufacturers.

Short Courses for Superintendents and Operators. This scheme has been followed successfully in many states. The courses are so arranged that those taking it are not in the least embarrassed by any lack of prior education. Much of the course is of a practical nature and the chemistry and biology lectures and laboratory work are made simple and attractive. Superintendents who have attended these schools have found them very helpful and have returned to take the courses another year, which is an excellent indication of their usefulness. Materials men, factory representatives, sales engineers and other specialists are called upon to give demonstrations of important equipment used in water works systems. All of this is very useful and helpful to the manufacturer as well as the "students." Questions are freely asked and answered.

I do not hesitate to recommend the Short Course to every one of you and I believe that you will find the slight expense and the time spent a thoroughly good investment.

Special and Unusual Problems. When a special or an unusual problem presents itself to water works or sewage works operators, information required may not be easily found in published form. In such instances the State Health Department personnel can be of material help and I can assure you, as a former operator and later affiliated with two State Departments of Health, that the engineers and chemists connected with the Department are always glad to assist the operator or the management of a public works wherever they can. Call freely on your Health Department Engineer for information and advice and you will be the gainer.

In instances, the problem will be of a nature that can be solved by utilizing information obtainable through the Research

*A paper presented before the Southeastern Section, American Water Works Association in 1932. Revised in 1937.

and Development Departments of manufacturers, Institutes, or Trade Associations. In my capacity of Research Engineer of the Chlorine Institute I have frequently been able to supply special information covering problems in chlorine application which, of nature, I was better prepared to give than someone else because of my long and intimate contact with chlorinating problems. Other associations are equipped to give similar service in connection with their products.

I have not understood why consulting engineers and chemists are not more regularly approached for advice and information covering special problems. I believe that managers of water and sewage systems overlook the value of having their municipality retain consultants on an annual fee basis in order to be in a position to seek advice as frequently as need be by mail or 'phone. This is practiced by some cities but as a rule the small municipalities, which would profit relatively more perhaps than the larger cities by such an arrangement, fail to take advantage of this relatively low cost service. Consultants are not prone to charge small municipalities as heavy as they would those more able to pay. Industry finds that it pays to retain consultants on an annual fee basis and it sems that municipalities should find the same.

I believe that every home should have its family physician and that every municipality needs the services of a consulting engineer to prescribe "remedies" over the 'phone just as the family physician does and thus frequently saves the patient much discomfort or prevents the necessity of a "major operation" later.

I find an increasing tendency on the part of small towns to retain chemists and engineers to supervise plant operations and at the same time supply advice and information whenever required. If engineers and chemists were as good salesmen as are lawyers and physicians, more of this kind of valuable service would be made use of.

Visiting. An excellent means of procuring information covering operation and maintenance is by visiting water and sewage works plants. Many of us are prone to inspect the works of our neighbors with a critical eye. We see too easily the weak points. If, on the other hand, we should look around and make inquiries in a less critical frame of mind, or with an attitude of seeking all possible information, more of value could be learned.

When one attends a water or sewage works meeting or a short course he is actually "visiting" because there he meets and tasks with men from other places. That is next in value to an actual visit or first hand inspection of the other fellow's works. I wish to stress the importance of visiting and exchanging experiences.

Acknowledgment. I acknowledge, with appreciation, the assistance of the several men who contributed suggestions of reference books, catalogs, etc., which proved helpful in preparing the following lists:

LIST NO. 1*—FOR WATER WORKS MANAGERS AND OPERATORS

[For Small and Moderate Size Systems.]

Books	*Publishers*	*Authors*
Water Works Practice—Manual of the A. W. W. A. ($5.00)	Williams & Wilkins, Baltimore	Various
Manual of Water Works Accounting (in preparation)	Am. Water Works Assn., New York City	Various
Manual of Water Purification Practice (in preparation)	Am. Water Works Assn., New York City	Various
The Operation of Water Filtration Plants (F)	N. C. State Dept. Health, Raleigh, N. C	
Water Supply Control (nominal charge)	N. Y. State Dept. Health, Albany, N. Y	
Water Works Handbook ($7.00)	McGraw-Hill Co., New York City	Flynn, Weston & Bogert
Water Purification Control, 2nd Edition ($1.75)	Williams & Wilkins, Baltimore, Md	Hopkins
Standard Methods of Water Analysis, 8th Ed. ($2.50)	A. P. H. A., New York City	A. W. W. A. & A. P. H. A.
Lab. Manual—Chemical & Bacterial Analysis Water and Sewage, 2nd Edition ($2.50)	McGraw Hill Co., New York City	Theroux, Eldridge, Mallman
Water Purification ($7.00)	McGraw Hill Co., New York City	Ellms
Copper Sulphate in Control of Micro Organisms (F)	Nichols Copper Co., New York City	Hale
Pump Data (F)	Economy Pumping Mach. Co., Chicago	
Conversion Factors for Engineers (F)	The Dorr Co., New York City	
Engineering Data in Flow of Fluids in Pipes (F)	Crane Co., Chicago	
Bul. No. 21 (a Handbook on Hydraulics) (F)	National Tube Co., Pittsburgh, Pa	
Handbook of Cast Iron Pipe (F)	Cast Iron Pipe Research Assn., Chicago	
Chlorination of Water	John Wiley & Sons, New York City****	Race
Technical Bulletins on Chlorination (F)	Wallace & Tiernan Co., Newark, N. J	Various
Reprints of Articles on Chlorine and Its Application (F)	The Chlorine Institute, New York City	Various
Hydraulic Tables—3rd Ed. ($2.00)	John Wiley & Sons, New York City	Williams & Hazen
Cameron Hydraulic Data (F)	Ingersoll-Rand, Phillipsburgh, N. J	
Handbook on Fire Protection ($4.50)	D. Van Nostrand Co., New York City	Crosby, Fiske & Forster
Fire Engine Tests and Fire Stream Tables (F)	National Board of Fire Underwriters, N. Y. C	
Plumber's Handbook ($4.00)	McGraw-Hill Co., New York City	Dibble
Examination of Water—6th Ed. ($3.00)	John Wiley & Sons, New York City	Mason & Buswell
Public Water Supplies—3rd Ed. ($6.00)	John Wiley & Sons, New York City	Turneau & Russell
American Civil Engineering Handbook—5th Ed. ($8.00)	John Wiley & Sons, New York City	Merriman & Wiggin
Lefax—Data Sheets for Loose Leaf Note Books	Lefax, Inc., Philadelphia, Pa	Various
Water Supply & Treatment (F)	National Lime Assn., Washington, D. C	Hoover
A. B. C. of Hydrogen Ion Control (F)	LaMotte Company, Baltimore, Md	
Modern P. H. Control (F)	W. A. Taylor Co., Baltimore, Md	
"Hydro-tite" Booklet of Useful Information (F)	Hydraulic Development Corp., New York, N. Y	
Microscopy of Drinking Water (in preparation)	John Wiley & Sons, New York City****	Whipple-Fair
Plane Surveying ($3.50)	John Wiley & Sons, New York City	Tracey
Water Treatment and Purification ($2.50)	McGraw Hill Co., New York City	Ryan

(F) Available as Free Publication at this writing, Apr., 1938.
*Revised and enlarged. Apr., 1938.
****Out of print. Try National Bibliophile Service, 347 Fifth Ave., N. Y. City.

Journals and Magazines (*Applies to Lists* 1 *and* 2)

Journal and Monographs of the American Waterworks Association
Journal of the New England Water Works Association.
Current Water Works Technical Magazines and Trade Papers.

LIST NO. 2*—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE WATER WORKS

(In addition to List No. 1 for smaller works)

Books	*Publishers*	*Authors*
Fresh Water Biology ($7.00)	John Wiley & Sons, New York City	Ward & Whipple
Fresh Water Algae ($6.00)	McGraw-Hill Co., New York City	Smith
Elements of Water Bacteriology—5th Ed. ($2.50)	John Wiley & Sons, New York City	Prescott & Winslow

"Industrial Water Supplies" (nominal charge)	Ohio Geological Survey, Columbus, Ohio	C. W. Foulk
pH and Its Practical Application ($3.50	Williams & Wilkins Co., Baltimore, Md.	LaMotte, Kenny & Reed
Elimination of Tastes and Odors in Water ($5.00)	McGraw-Hill Co., New York City	Baylis
Boiler Feedwater Purification ($4.00)	McGraw-Hill Co., New York City	Powell
Chemistry of Water and Sewage Treatment****	Chemical Catalog Company, New York City****	Buswell
Water Borne Typhoid Fever Outbreaks (nominal)	Am. Public Health Bureau	Wolman & Gorman
Textbook of Bacteriology ($8.00)	D. Appleton & Co., New York City	Zinser & Jones
Corrosion; Causes and Prevention ($7.00)	McGraw-Hill Co., New York City	Speller
Water Supply Paper No. 658 (Quality of Waters) (nominal)	U. S. Geological Survey, Washington, D. C.	Stabler
Water Supply Engineering ($6.00)	McGraw-Hill Co., New York City	Babbitt & Doland
Handbook of Hydraulics ($4.00)	McGraw-Hill Co., New York City	King
Concrete Engineers' Handbook ($6.00)	McGraw-Hill Co., New York City	Hool & Johnson
Pocket Companion (nominal)	Carnegie Steel Corp., New York City	
Business Law for Engineers ($4.00)	McGraw-Hill Co., New York City	Allen
Mechanical Engineers' Handbook—11th Ed. ($5.00)	John Wiley & Sons, New York City	Kent
Elements of Hydraulics ($1.50)	John Wiley & Sons, New York City	Merriman
Guiding Principles of Public Service Regulations (3 Vols.)	Public Utilities Reports, Inc., Rochester, N. Y.	Spurr
Theory and Practice of Public Utility Valuation****	McGraw-Hill Co., New York City****	Maltbie
Public Utility Rates****	McGraw-Hill Co., New York City****	Barker
Public Utility Rate Structures ($4.00)	McGraw-Hill Co., New York City	*Nash*
Census of Munic. Water Purification Plants (nominal)	Am. Water Works Assn., New York City	
Business Administration for Engineers ($5.00)	McGraw-Hill Co., New York City	Harding & Canfield
Census of Municipal Water Purification Plants (50c)	Am. Water Wks. Assn., New York City	
Index to Jour. of A. W. W. A.—1881-1933 ($2.50)	Am. Water Wks. Assn., New York City	

(F) Available as Free Publication at this writing, Apr., 1938.
*Revised and enlarged. Apr., 1938.
****Out of print. Try National Bibliophile Service, 347 Fifth Ave., N. Y. City.

For Journals see list No. 1.

LIST NO. 3*—FOR OPERATORS AND MANAGERS OF SMALL SEWAGE WORKS**

Books	*Publishers*	*Authors*
Operation and Control of Sewage Treatment Plants (F)	New York State Dept. Health	N. Y. State Dept. Health
Arithmetic of Sewage Disposal $2.00)	John Wiley & Sons, New York City	Imhoff & Fair
Sewerage and Sewage Disposal Text Book ($6.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Bulletins Nos. 59, 68, 69, 84 and 86 (F)	Iowa State College, Ames, Iowa	Various
Manual of Sewage Works Operation (nominal)	New Jersey Sewage Expt. Sta., New Brunswick, N. J.	
Reprints of Technical Papers on Chlorine in Sewage Treatment (F)	Wallace & Tiernan Co., Newark, N. J., and The Chlorine Inst., N. Y. C.	
Chlorination in Sewage Treatment (F)	Amer. Pub. Health Assn., N. Y. C.	Committee Reports
Chemical Treatment of Sewage (nominal)	Amer. Pub. Health Assn., N. Y. C.	Committee Report
Standard Methods of Water and Sewage Analysis ($2.50)	Amer. Pub. Health Assn., N. Y. C.	A. W. W. A.-A. P. H. A.
Laboratory Manual of Water and Sewage Analysis ($2.50)	McGraw-Hill Co., New York City	Theroux, Eldridge & Mallman
Sewage Works Journal—(Official publication of the Federation of Sewage Wks. Assns.)		
Current Sewerage Magazines		

*Revised and enlarged, Apr., 1938.

LIST NO. 4*—FOR MANAGER, CHEMISTS AND OPERATORS OF LARGE SEWAGE WORKS**

(In addition to List No. 3 for smaller works)

Books	*Publishers*	*Authors*
American Sewage Practice Vol. 3, Sewage Treatment (1935 Edition) ($7.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Solving Sewage Problems ($6.00)	McGraw-Hill Co., New York City	Fuller & McClintock
Sewerage and Sewage Treatment—4th Ed. ($5.00)	John Wiley & Sons, New York City	Babbitt
The Chemistry of Water and Sewage Treatment****	Chemical Catalog Co., New York****	Buswell
The Hoover Plumbing Code (B. H. 13) (nominal)	U. S. Bureau of Standards	
Sewerage and Sewage Treatment ($3.50)	Intl. Text Book Co., Scranton, Pa.	Hardenberg
Sewerage, 11th Ed. ($4.50)	John Wiley & Sons, New York City	Folwell
Sewage Disposal****	John Wiley and Sons, New York City****	Kinnicutt, Winslow & Pratt

(F) Available as Free Publication at this writing, Apr., 1938.
*Revised and enlarged. Apr., 1938.
****Out of print. Try National Bibliophile Service, 347 Fifth Ave., N. Y. City.

Journals and Magazines (Applies to Lists 3 and 4)

**Note*—Sewerage men should examine Lists 1 and 2—also for several (F) publications of value to all alike—for instance, "Conversion Factors for Engineers" and the hand-books of pipe and pump data.

WATER

A Discussion of Flows, Friction, Measurement and Power*

The rate of flow or the volume of water passing a cross section of a stream in a unit time is called the "discharge." If a uniform velocity at all points in the cross section of a stream were possible, there would be passing any cross section of the stream, every unit of time, a prism of water having a base equal to the cross-sectional area of the stream and a length equal to the velocity. However, due to the varying effects of friction and viscosity, the different filaments of water move with different velocities. For this reason it is common in hydraulics to deal with "mean velocities."

The discharge may be expressed in terms of the mean velocity:

$$Q = av$$

where Q = Discharge in cubic feet per second.
a = Cross-sectional area of stream in square feet.
v = Mean velocity in feet per second.

When the discharge is constant (i.e., when the same quantity of water passes any cross section of a stream during equal successive intervals of time) the flow is said to be "steady."

Flow is said to be "uniform" when there is little or no change in the cross section or velocity from point to point in a stream.

Thus uniform flow implies similarity of conditions at successive cross sections at any given instant, while steady flow involves permanency of conditions at any particular cross section.

In hydraulics the term "pressure head," "static head" or simply "head" is used to designate the vertical height of a static column of liquid which, due to its weight, would produce a pressure equivalent to the pressure in the fluid at the point in question.

The "velocity head" is the height through which a body must fall in a vacuum to acquire the velocity with which water flows in a stream. The velocity head corresponding to any velocity is equal to the static head, which (neglecting friction) could cause (or could be caused by) that velocity. The relation between velocity head and velocity may be expressed by the formula:

$$h_v = \frac{v^2}{2g}$$

where h_v = Velocity head in feet.
v = Mean velocity in feet per second.
g = Acceleration of gravity = 32.174 feet per second per second.

Flow of Water Through Orifices and Tubes

As commonly used in hydraulics, the term orifice is used to designate an opening with a closed perimeter, and of regular shape, through which water flows. If the perimeter is not closed, or if the opening flows only partially full, the orifice becomes a weir.

An orifice with prolonged sides, such as a short piece of pipe two or three diameters in length, set in the side of a reservoir, is called a tube. An orifice in a thick wall has the hydraulic properties of a tube.

The theoretical velocity of a stream or jet of water issuing from an orifice is given by the formula:

$$v_t = \sqrt{2gh}$$

where v_t = Theoretical velocity in feet per second.
g = Acceleration of gravity = 32.174 feet per second per second.
h = Head on the center of the orifice in feet.

The actual velocity of the jet is less than the theoretical velocity because of the frictional loss which occurs as the water approaches the orifice. The ratio of the actual mean velocity, v, to the theoretical velocity, v_t, is called the "velocity coefficient" and is designated by the symbol C_v. The actual mean velocity of the jet is therefore:

$$v = C_v\sqrt{2gh}$$

The stream or jet issuing from an orifice is not in all cases the same size as the opening of the orifice because of contraction effects in certain cases and flaring effects in other cases. The "contraction coefficient," C_c, of an orifice is the ratio of the cross-sectional area of the jet to that of the orifice.

The discharge from an orifice is given by the formula:

$$Q = C_vC_ca\sqrt{2gh}$$

where Q = Discharge in cubic feet per second.
a = Area of orifice opening in square feet.

It is customary to combine the coefficients C_v and C_c into a single coefficient C_d which is called a "discharge coefficient." The discharge coefficient is therefore a product of the velocity coefficient and the contraction coefficient, or $C_d = C_v \times C_c$.

The formula for discharge from an orifice then becomes:

$$Q = C_da\sqrt{2gh}$$

Table 12 gives average values of discharge coefficients for various types of orifices and tubes.

Flow of Water in Pipe and Open Channels

As the term is used in hydraulics, a pipe may be defined as a closed conduit which flows full under pressure. By open channel is meant any kind of water course with the top surface of the flowing water exposed to the atmosphere, such as a canal, aqueduct, flume, sewer or river.

The "wetted perimeter" of any conduit is that portion of the perimeter of the cross section of the conduit in contact with the liquid.

The "hydraulic radius" of a conduit is the cross-sectional area of the stream, divided by the wetted perimeter of that section. For a circular pipe flowing either full or half full the hydraulic radius is one-fourth the pipe diameter (or one-half the pipe radius).

If a tube is tapped into the wall of a vessel or pipe containing water under pressure, the water will rise in the tube to a height equal to the head producing the pressure at the point where the tube is inserted. Such a tube is called a "piezometer" tube. Piezometer tubes measure pressure above atmospheric pressure (gage pressure) since the water surface in the tube is subjected to atmospheric pressure. When piezometer tubes are used to measure pressure heads in pipes where water is in mo-

Table 12

Discharge Coefficients for Various Types of Orifices and Tubes

Diagram	Description	Average discharge coefficient, C_d
	SHARP-EDGED ORIFICE The stream is contracted to about 0.62 of the area of the opening.	0.61
	ORIFICE WITH WELL-ROUNDED ENTRY There is little or no contraction and the stream is about the same size as the opening.	0.98
	SHORT TUBE OR ORIFICE IN THICK WALL WITH SQUARE-EDGED ENTRY When flowing full. When the length of the tube is 2½ diameters it is called a "standard short tube".	0.82
	SHORT TUBE OR ORIFICE IN THICK WALL WITH SQUARE-EDGED ENTRY When the stream springs clear from the tube at the upstream corner the flow is the same as for a sharp-edged orifice.	0.61
	RE-ENTRANT TUBE Length about 2½ diameters. Flowing full.	0.73
	RE-ENTRANT TUBE When the length is about one diameter it is called "Borda's Mouthpiece". Stream springs clear of the walls of the tube.	0.52

*The material under this heading has been drawn from Technical Bulletin No. 21, recently issued by National Tube Co. of Pittsburgh, Pa.—Ed.

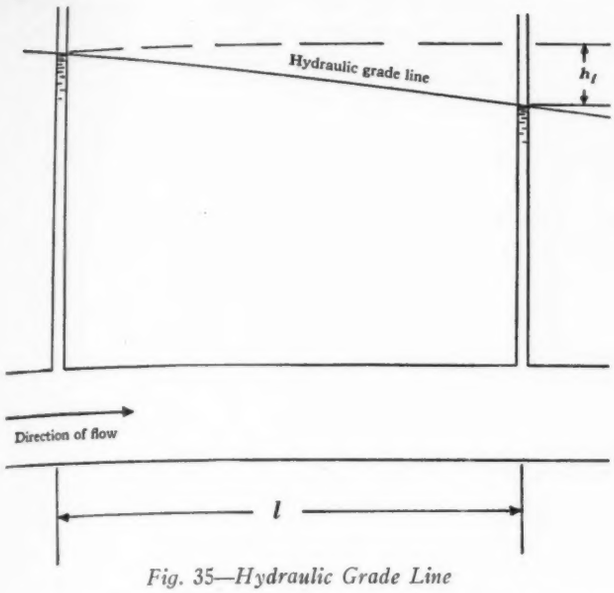


Fig. 35—Hydraulic Grade Line

tion, the end of the tube should enter the pipe at right angles to the direction of flow and the end of the tube should be flush with the inner surface of the pipe.

If a pipe full of water is provided with several piezometer tubes, a line joining the tops of the columns of water in the tubes is called the "hydraulic grade line," and the slope of this line is the "hydraulic slope" or simply the "slope." Two piezometer tubes attached to a pipe line are shown in Fig. 35. The line joining the tops of the columns of water in the tubes represents the hydraulic grade line and h_f represents the loss of head in length l. The hydraulic slope, s, is therefore:

$$s = \frac{h_f}{l}.$$

Friction

There is always friction between moving water and the surface with which the water comes into contact. There is also friction between the moving particles of the water themselves which is commonly called viscosity.

Water particles in contact with the conduit surface are retarded by friction, and viscosity causes a retardation of the particles removed from the conduit surface. Therefore, water flowing in a pipe has its maximum velocity at the center and its minimum velocity near the pipe walls.

If there were no friction losses, the theoretical velocity, v_t, at which water would discharge from a pipe or channel would be $v_t = \sqrt{2gh}$. In any long pipe or channel, however, the greater portion of the total head is used in overcoming friction.

The amount of frictional resistance offered by any surface increases with the degree of roughness of the surface. The resistance due to viscosity decreases as the temperature of the water increases.

The loss of head due to the combined effects of viscosity and friction between the moving water and the surface of the conduit is usually referred to as the loss of head due to friction.

The influences of friction and viscosity on the flow of water have been determined experimentally by various authorities and a variety of formulas for the loss of head due to friction have been derived. Only a few of the best-known and most generally used formulas will be presented in this article.

In addition to the loss of head due to friction, other losses of head result from changing the velocity or direction of flow. These special losses are considered in Table 21.

Formulas for Flow of Water In Pipe and Open Channels

The Chezy Formula

The most generally used formula for determining the velocity of flow of water in pipe and open channels is the Chezy Formula:

$$v = c\sqrt{rs}, \text{ or } v = cr^{0.5}s^{0.5}$$

where v = Mean velocity in feet per second.
r = Hydraulic radius in feet.
s = Hydraulic slope in feet per foot of length.
c = A coefficient which Chezy considered to be constant, but which is now known to vary with the hydraulic slope and hydraulic radius as well as with the degree of roughness of the surface with which the water comes in contact.

This formula, although originally designed for open channels, is with proper modification applicable to either open channels or pipe.

The Hazen-Williams Formula

For the same degree of roughness, the value of c for the Chezy Formula increases with the hydraulic slope and with the hydraulic radius. This is due to the fact that the exponents used for the terms in the formula are less than the true values. If the exponents were increased to correspond more nearly with the facts, the variation in the value of c would become smaller.

The Hazen-Williams Formula was designed with a view of obtaining a minimum variation in the value of c for all conduits of the same degree of roughness. That is, the object was to select values for the exponents such that c would be, as nearly as practicable, a function of the degree of roughness of the conduit surface and not of the hydraulic radius and slope.

The Hazen-Williams Formula is:

$$v = cr^{0.63}s^{0.54}0.001^{-0.04}$$

where v = Mean velocity in feet per second.
r = Hydraulic radius in feet.
s = Hydraulic slope in feet per foot of length.
c = Hazen-Williams coefficient of roughness.

The last term $(0.001^{-0.04})$ is a constant, and was introduced simply to equalize the value of c with the value in the Chezy Formula and other exponential formulas which may be used as a slope of 0.001 instead of at a slope of 1. Since $0.001^{-0.04}$ equals 1.318, the Hazen-Williams Formula may be written:

$$v = 1.318cr^{0.63}s^{0.54}$$

Values of Coefficient "C"

The following values of the coefficient c may be used in the Hazen-Williams Formula for computing the loss of head due to friction in new well-laid pipe:

Kind of Pipe	Coefficient c	Kind of Pipe	Coefficient c
National Duroline	148*†	Wood Stave	120
Wrought Steel	140	Riveted Steel	110
Small Brass and Copper	130	Vitrified Pipe	110
Cast Iron	130	Brick Sewers	100
Concrete	120		

*"Duroline" pipe is protected against internal corrosion and mounting friction losses by a cement base composition lining of a highly durable nature.—Ed.

†Approximately the same for cement lined pipe.—Ed.

It must be understood that these values depend upon the smoothness and regularity of the surfaces and are likely to vary in individual cases. In designing a pipe line it is customary to use somewhat lower coefficients than those above, to allow for variations due to local conditions, and for reduction of carrying capacity with age due to roughening of the inside surface, accumultaion of corrosion products, and tuberculation. However, in case of Duroline Pipe, the volume of flow remains practically unchanged over long periods of service due to the fact that rust tubercles do not form and the initially smooth inside surface is retained.

Tables 15 and 16 have been prepared to furnish directly the loss of head (h_f) in feet per 1000 feet of pipe of various sizes for different velocities and values of the coefficient c. Similar data for Duroline Pipe, based on a value of $c = 148$, is given in Table 17. These tables were calculated for actual internal diameters by the following arrangement of the Hazen-Williams Formula:

$$h_f = 1000\sqrt[0.54]{\frac{v}{1.318\,cr^{0.63}}}$$

where h_f = Loss of head in feet due to friction per 1000 feet of pipe = $1000s$.

The loss of head (h_f) for any value of the coefficient c not given in Tables 15 and 16 may be determined by multiplying the loss of head (h_f) for $c = 100$ by the factor $\sqrt[0.54]{\frac{100}{c}}$

Values of this factor corresponding to various values of the coefficient c are given below:

Coefficient c	Factor $= \sqrt[0.54]{\frac{100}{c}}$	Coefficient c	Factor $= \sqrt[0.54]{\frac{100}{c}}$
60	2.575	110	0.8382
70	1.936	120	.7135
80	1.512	130	.6152
90	1.215	140	.5363
100	1.000		

Table 15
Loss of Head in Pipe by Friction for National A.P.I. Line Pipe, Calculated by Hazen-Williams Formula

Pipe size inches	Inside diameter inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=120$	$c=100$	$c=80$
1	1.049	3	4,320	1.114	6.72	3.94	12.5	18.9
		4	5,760	1.485	11.4	15.2	21.4	32.3
		5	7,200	1.856	17.3	23.0	32.3	48.8
		6	8,640	2.227	24.3	32.3	45.2	68.4
		8	11,520	2.970	41.3	55.0	77.1	117.
		10	14,400	3.712	62.5	83.1	117.	176.
		12	17,280	4.455	87.6	117.	163.	247.
		16	23,040	5.940	149.	198.	278.	421.
		20	28,800	7.425	226.	300.	421.	636.
		25	36,000	9.281	341.	454.	636.	961.
		30	43,200	11.137	478.	636.	891.	1347.
		35	50,400	12.993	636.	846.	1185.	1792.
		40	57,600	14.849	814.	1083.	1518.	2295.
1¼	1.380	4	5,760	0.858	3.01	4.01	5.61	8.49
		5	7,200	1.073	4.55	6.06	8.49	12.8
		6	8,640	1.287	6.38	8.49	11.9	18.0
		8	11,520	1.716	10.9	14.5	20.3	30.6
		10	14,400	2.145	16.4	21.9	30.6	46.3
		12	17,280	2.574	23.0	30.6	42.9	64.9
		16	23,040	3.432	39.2	52.2	73.2	111.
		20	28,800	4.290	59.3	78.9	111.	167.
		30	43,200	6.435	126.	167.	234.	354.
		40	57,600	8.580	214.	285.	399.	603.
		60	86,400	12.870	454.	603.	846.	1279.
		80	115,200	17.160	773.	1028.	1441.	2178.
1½	1.610	4	5,760	0.630	1.42	1.89	2.65	4.01
		5	7,200	.788	2.15	2.86	4.00	6.06
		6	8,640	.946	3.01	4.01	5.62	8.49
		8	11,520	1.261	5.13	6.82	9.57	14.5
		10	14,400	1.576	7.76	10.3	14.5	21.9
		12	17,280	1.891	10.9	14.5	20.3	30.6
		16	23,040	2.521	18.5	24.6	34.5	52.2
		20	28,800	3.152	28.0	37.2	52.2	78.9
		30	43,200	4.728	59.3	78.9	111.	167.
		50	72,000	7.880	153.	203.	285.	431.
		75	108,000	11.820	324.	431.	603.	912.
		100	144,000	15.759	551.	734.	1028.	1554.
		125	180,000	19.699	833.	1109.	1554.	2350.
2	2.067	6	8,640	0.574	0.892	1.19	1.66	2.51
		8	11,520	765	1.52	2.02	2.83	4.28
		10	14,400	956	2.30	3.06	4.28	6.47
		12	17,280	1.147	3.22	4.28	6.00	9.07
		16	23,040	1.530	5.48	7.30	10.2	15.5
		20	28,800	1.912	8.29	11.3	15.5	23.3
		30	43,200	2.868	17.6	23.4	32.8	49.5
		50	72,000	4.781	45.2	60.2	84.3	128.
		75	108,000	7.171	95.8	128.	179.	270.
		100	144,000	9.561	163.	217.	304.	460.
		150	216,000	14.342	346.	460.	645.	975.
		200	288,000	19.122	589.	784.	1099.	1661.

Pipe size inches	Inside diameter inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
2½	2.469	8	11,520	0.536	0.639	0.733	0.851	1.10
		10	14,400	.670	.966	1.11	1.29	1.80
		12	17,280	.804	1.35	1.55	1.80	2.53
		16	23,040	1.072	2.31	2.65	3.07	4.30
		20	28,800	1.340	3.49	4.00	4.64	6.51
		25	36,000	1.675	5.27	6.05	7.02	9.83
		50	72,000	3.351	19.0	21.8	25.3	35.5
		100	144,000	6.701	68.7	78.8	91.4	128.
		150	216,000	10.052	146.	167.	194.	271.
		200	288,000	13.402	248.	284.	330.	462.
		250	360,000	16.753	375.	430.	499.	699.
		300	432,000	20.103	526.	603.	699.	980.
3	3.068	10	14,400	0.434	0.336	0.385	0.446	0.626
		15	21,600	.651	.711	.816	.946	1.33
		20	28,800	.868	1.21	1.39	1.61	2.26
		25	36,000	1.085	1.83	2.10	2.44	3.41
		50	72,000	2.170	6.61	7.58	8.79	12.3
		100	144,000	4.340	23.9	27.4	31.7	44.5
		200	288,000	8.680	86.1	98.8	115.	161.
		300	432,000	13.020	182.	209.	243.	340.
		400	576,000	17.360	311.	357.	414.	580.
		500	720,000	21.699	470.	539.	625.	876.
3½	3.548	10	14,400	0.325	0.165	0.190	0.220	0.308
		15	21,600	.487	.350	.402	.466	.653
		20	28,800	.649	.597	.684	.794	1.11
		25	36,000	.811	.902	1.03	1.20	1.68
		50	72,000	1.623	3.26	3.73	4.33	6.07
		100	144,000	3.245	11.8	13.5	15.6	21.9
		200	288,000	6.490	42.4	48.7	56.4	79.1
		300	432,000	9.735	89.9	103.	120.	168.
		400	576,000	12.980	153.	176.	204.	286.
		500	720,000	16.225	231.	266.	308.	432.
		600	864,000	19.470	324.	372.	432.	605.
4	4.026	20	28,800	0.504	0.322	0.370	0.429	0.601
		25	36,000	.630	.487	.559	.648	.909
		30	43,200	.756	.683	.784	.909	1.27
		40	57,600	1.008	1.16	1.33	1.55	2.17
		50	72,000	1.260	1.76	2.02	2.34	3.28
		100	144,000	2.520	6.35	7.28	8.45	11.8
		200	288,000	5.040	22.9	26.3	30.5	42.7
		300	432,000	7.561	48.6	55.7	64.6	90.6
		400	576,000	10.081	82.7	94.9	110.	154.
		500	720,000	12.601	125.	143.	166.	233.
		600	864,000	15.121	175.	201.	233.	327.
		800	1,152,000	20.162	299.	343.	397.	557.

Pipe size inches	Inside diameter inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
5	5.047	30	43,200	0.481	0.227	0.261	0.302	0.424
		40	57,600	.642	.387	.444	.515	.722
		50	72,000	.802	.585	.671	.779	1.09
		100	144,000	1.604	2.11	2.42	2.81	3.94
		200	288,000	3.208	7.63	8.75	10.1	14.2
		300	432,000	4.812	16.2	18.5	21.5	30.1
		400	576,000	6.416	27.5	31.6	36.6	51.3
		500	720,000	8.020	41.6	47.7	55.3	77.6
		750	1,080,000	12.030	88.2	101.	117.	164.
		1000	1,440,000	16.040	150.	172.	200.	280.

Pipe size inches	Inside diameter inches	Discharge in Gallons per 24 hours	Discharge in Cubic feet per second	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
6	6.065	50,000	0.0774	0.386	0.122	0.140	0.162	0.227
		60,000	0.928	.463	.171	.196	.227	.318
		80,000	.124	.617	.291	.333	.387	.542
		100,000	.155	.771	.439	.504	.585	.819
		200,000	.309	1.542	1.59	1.82	2.11	2.96
		300,000	.464	2.314	3.36	3.85	4.47	6.27
		400,000	.619	3.085	5.72	6.57	7.62	10.7
		600,000	.928	4.627	12.1	13.9	16.1	22.6
		800,000	1.238	6.170	20.7	23.7	27.5	38.5
		1,000,000	1.547	7.712	31.2	35.8	41.6	58.2
		1,500,000	2.321	11.568	66.2	75.9	88.1	123.
		2,000,000	3.094	15.424	113.	129.	150.	210.
8	7.981	200,000	0.309	0.891	0.416	0.478	0.554	0.777
		300,000	.464	1.336	.882	1.01	1.17	1.65
		400,000	.619	1.781	1.50	1.72	2.00	2.80
		500,000	.774	2.227	2.27	2.61	3.02	4.24
		750,000	1.160	3.340	4.82	5.52	6.41	8.98
		1,000,000	1.547	4.454	8.20	9.41	10.9	15.3
		1,500,000	2.321	6.680	17.4	19.9	23.1	32.4
		2,000,000	3.094	8.907	29.6	34.0	39.4	55.2
		3,000,000	4.642	13.361	62.7	72.0	83.5	117.
10	10.020	300,000	0.464	0.848	0.291	0.334	0.388	0.543
		400,000	.619	1.130	.496	.569	.660	.926
		500,000	.774	1.413	.750	.861	.998	1.40
		750,000	1.160	2.119	1.59	1.82	2.12	2.96
		1,000,000	1.547	2.825	2.71	3.11	3.60	5.05
		2,000,000	3.094	5.651	9.78	11.2	13.0	18.2

Pipe size inches	Inside diameter inches	Discharge in Gallons per 24 hours	Discharge in Cubic feet per second	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
10	10.020	3,000,000	4.642	8.476	20.7	23.8	27.6	38.6
		4,000,000	6.189	11.302	35.3	40.5	47.0	65.8
		5,000,000	7.736	14.127	53.4	61.2	71.0	99.5
12	12.000	300,000	0.464	0.591	0.121	0.139	0.161	0.226
		400,000	.619	.788	.206	.237	.274	.385
		500,000	.774	.985	.312	.358	.415	.581
		1,000,000	1.547	1.970	1.13	1.29	1.50	2.10
		1,500,000	2.321	2.955	2.38	2.74	3.17	4.45
		2,000,000	3.094	3.940	4.06	4.66	5.40	7.58
		3,000,000	4.642	5.910	8.61	9.87	11.5	16.1
		5,000,000	7.736	9.850	22.2	25.4	29.5	41.3
		7,500,000	11.60	14.775	47.0	53.9	62.5	87.6
		10,000,000	15.47	19.700	80.0	91.8	106.	149.
14 O D	13.250	500,000	0.774	0.808	0.192	0.221	0.256	0.359
		1,000,000	1.547	1.616	.695	.797	.924	1.30
		2,000,000	3.094	3.232	2.51	2.88	3.34	4.68
		3,000,000	4.642	4.847	5.31	6.09	7.07	9.91
		5,000,000	7.736	8.079	13.7	15.7	18.2	25.5
		7,500,000	11.60	12.119	29.0	33.3	38.6	54.1
		10,000,000	15.47	16.158	49.4	56.6	65.7	92.1
		12,500,000	19.34	20.198	74.7	85.6	99.3	139.
16 O D	15.250	750,000	1.160	0.915	0.206	0.236	0.274	0.383
		1,000,000	1.547	1.220	.350	.402	.466	.653
		2,000,000	3.094	2.440	1.26	1.45	1.68	2.36
		3,000,000	4.642	3.659	2.68	3.07	3.56	5.00
		5,000,000	7.736	6.099	6.90	7.91	9.18	12.9
		7,500,000	11.60	9.148	14.6	16.8	19.4	27.3
		10,000,000	15.47	12.198	24.9	28.6	33.1	46.4
		15,000,000	23.21	18.297	52.8	60.5	70.2	98.4
18 O D	17.182	1,000,000	1.547	.961	0.196	0.225	0.261	0.365
		2,000,000	3.094	1.922	.707	.811	.941	1.32
		3,000,000	4.642	2.883	1.50	1.72	1.99	2.79
		5,000,000	7.736	4.805	3.86	4.43	5.13	7.20
		7,500,000	11.60	7.207	8.18	9.38	10.9	15.2
		10,000,000	15.47	9.609	13.9	16.0	18.5	26.0
		15,000,000	23.21	14.414	29.5	33.9	39.3	55.0
		20,000,000	30.94	19.218	50.3	57.7	66.9	93.8
20 O D	19.182	1,000,000	1.547	0.771	0.115	0.131	0.152	0.214
		2,000,000	3.094	1.542	.414	.475	.550	.771
		3,000,000	4.642	2.313	.876	1.01	1.17	1.63
		5,000,000	7.736	3.855	2.26	2.59	3.00	4.21
		7,500,000	11.60	5.782	4.78	5.49	6.36	8.92
		10,000,000	15.47	7.710	8.15	9.35	10.8	15.2
		15,000,000	23.21	11.565	17.3	19.8	23.0	32.2
		20,000,000	30.94	15.419	29.4	33.7	39.1	54.8

Table 16

Loss of Head in Pipe by Friction for Large Diameter Pipe Listed by I. D. Sizes, Calculated by Hazen-Williams Formula

Pipe inside diameter		Discharge in		Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f)			
Inches	Feet (D)	Million gallons per 24 hours	Cubic feet per second		c=140	c=130	c=120	c=100
22	1.8333	1	1.547	0.586	0.059	0.067	0.078	0.110
		2.5	3.868	1.465	.321	.368	.427	.598
		5	7.736	2.931	1.16	1.33	1.54	2.16
		7.5	11.60	4.396	2.45	2.81	3.26	4.57
		10	15.47	5.861	4.18	4.79	5.56	7.79
		15	23.21	8.792	8.86	10.2	11.8	16.5
		20	30.94	11.722	15.1	17.3	20.1	28.1
		25	38.68	14.653	22.8	26.2	30.3	42.5
24	2.0000	2	3.094	0.985	0.139	0.159	0.185	0.259
		5	7.736	2.462	.758	.869	1.01	1.41
		7.5	11.60	3.694	1.61	1.84	2.14	2.99
		10	15.47	4.925	2.74	3.14	3.64	5.10
		15	23.21	7.387	5.80	6.65	7.71	10.8
		20	30.94	9.850	9.87	11.3	13.1	18.4
		25	38.68	12.312	14.9	17.1	19.9	27.8
		30	46.42	14.775	20.9	24.0	27.8	39.0
26	2.1667	2	3.094	0.839	0.094	0.108	0.125	0.175
		5	7.736	2.098	.513	.589	.683	.957
		7.5	11.60	3.147	1.09	1.25	1.45	2.03
		10	15.47	4.196	1.85	2.12	2.46	3.45
		15	23.21	6.295	3.93	4.50	5.22	7.32
		20	30.94	8.393	6.69	7.67	8.90	12.5
		25	38.68	10.491	10.1	11.6	13.4	18.8
		30	46.42	12.589	14.2	16.3	18.8	26.4
28	2.3333	2	3.094	0.724	0.066	0.075	0.087	0.122
		5	7.736	1.809	.358	.410	.476	.667
		7.5	11.60	2.714	.758	.869	1.01	1.41
		10	15.47	3.618	1.29	1.48	1.72	2.41
		15	23.21	5.428	2.74	3.14	3.64	5.10
		20	30.94	7.237	4.66	5.35	6.20	8.69
		25	38.68	9.046	7.05	8.08	9.37	13.1
		30	46.42	10.855	9.88	11.3	13.1	18.4
30	2.5000	5	7.736	1.576	0.256	0.293	0.340	0.477
		10	15.47	3.152	.923	1.06	1.23	1.72
		15	23.21	4.728	1.96	2.24	2.60	3.65
		20	30.94	6.304	3.33	3.82	4.43	6.21
		25	38.68	7.880	5.03	5.78	6.70	9.39
		30	46.42	9.456	7.06	8.10	9.39	13.2
		35	54.15	11.032	9.39	10.8	12.5	17.5
		40	61.89	12.608	12.0	13.8	16.0	22.4
36	3.0000	5	7.736	1.094	0.105	0.121	0.140	0.196
		10	15.47	2.189	.380	.436	.505	.708
		15	23.21	3.283	.804	.923	1.07	1.50
		20	30.94	4.378	1.37	1.57	1.82	2.56
		30	46.42	6.567	2.90	3.33	3.86	5.41
		40	61.89	8.756	4.95	5.67	6.58	9.22
		50	77.36	10.944	7.48	8.58	9.95	13.9
		60	92.83	13.133	10.5	12.0	13.9	19.5

Pipe inside diameter		Discharge in		Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f)			
Inches	Feet (D)	Cubic feet per second	Million gallons per 24 hours		c=140	c=130	c=120	c=100
78	6.50	25	16.16	0.753	0.021	0.025	0.028	0.040
		50	32.32	1.507	.077	.089	.103	.144
		75	48.47	2.260	.163	.188	.217	.305
		100	64.63	3.014	.278	.319	.371	.519
		150	96.95	4.520	.590	.677	.785	1.10
		200	129.3	6.027	1.01	1.15	1.34	1.87
		250	161.6	7.534	1.52	1.74	2.02	2.83
		300	193.9	9.041	2.13	2.44	2.83	3.97
84	7.00	25	16.16	0.650	0.015	0.017	0.020	0.028
		50	32.32	1.299	.054	.062	.072	.100
		75	48.47	1.949	.114	.131	.152	.212
		100	64.63	2.598	.194	.223	.258	.362
		150	96.95	3.898	.411	.472	.547	.767
		200	129.3	5.197	.701	.804	.932	1.31
		250	161.6	6.496	1.06	1.22	1.41	1.98
		300	193.9	7.795	1.48	1.70	1.98	2.77
90	7.50	25	16.16	0.566	0.011	0.012	0.014	0.020
		50	32.32	1.132	.038	.044	.051	.072
		75	48.47	1.698	.081	.093	.108	.152
		100	64.63	2.264	.139	.159	.185	.259
		150	96.95	3.395	.294	.337	.391	.548
		200	129.3	4.527	.501	.574	.666	.934
		300	193.9	6.791	1.06	1.22	1.41	1.98
		400	258.5	9.054	1.81	2.07	2.40	3.37
96	8.00	25	16.16	0.497	0.008	0.009	0.010	0.014
		50	32.32	0.995	.028	.032	.037	.052
		100	64.63	1.989	.101	.116	.135	.189
		150	96.95	2.984	.215	.246	.286	.400
		200	129.3	3.979	.366	.419	.486	.682
		300	193.9	5.968	.775	.889	1.03	1.44
		400	258.5	7.958	1.32	1.51	1.76	2.46
		500	323.2	9.947	2.00	2.29	2.65	3.72

Pipe inside diameter		Discharge in		Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f)			
Inches	Feet (D)	Million gallons per 24 hours	Cubic feet per second		c=140	c=130	c=120	c=100
42	3.50	5	7.736	0.804	0.050	0.057	0.066	0.093
		10	15.47	1.608	.179	.206	.238	.334
		15	23.21	2.412	.380	.436	.505	.708
		20	30.94	3.216	.647	.742	.861	1.21
		30	46.42	4.824	1.37	1.57	1.82	2.56
		40	61.89	6.433	2.34	2.68	3.11	4.35
		50	77.36	8.041	3.53	4.05	4.70	6.58
		75	116.0	12.061	7.48	8.58	9.95	13.9
48	4.00	5	7.736	0.616	0.026	0.030	0.034	0.048
		10	15.47	1.231	.094	.107	.124	.174
		20	30.94	2.462	.338	.387	.449	.630
		30	46.42	3.694	.715	.821	.952	1.33
		40	61.89	4.925	1.22	1.40	1.62	2.27
		50	77.36	6.156	1.84	2.11	2.45	3.44
		75	116.0	9.234	3.90	4.48	5.19	7.28
		100	154.7	12.312	6.65	7.63	8.85	12.4
54	4.50	10	15.47	0.973	0.053	0.060	0.070	0.098
		20	30.94	1.946	.190	.218	.253	.355
		30	46.42	2.919	.403	.462	.536	.752
		40	61.89	3.891	.687	.788	.913	1.28
		50	77.36	4.864	1.04	1.19	1.38	1.94
		75	116.0	7.296	2.20	2.52	2.93	4.10
		100	154.7	9.728	3.75	4.30	4.98	6.99
		125	193.4	12.160	5.66	6.50	7.54	10.6
60	5.00	10	15.47	0.788	0.032	0.036	0.042	0.059
		20	30.94	1.576	.114	.131	.151	.212
		30	46.42	2.364	.241	.277	.321	.450
		40	61.89	3.152	.411	.471	.547	.766
		50	77.36	3.940	.621	.713	.827	1.16
		75	116.0	5.910	1.32	1.51	1.75	2.45
		100	154.7	7.880	2.24	2.57	2.98	4.18
		125	193.4	9.850	3.39	3.89	4.51	6.32
66	5.50	10	15.47	0.651	0.020	0.023	0.026	0.037
		20	30.94	1.302	.072	.082	.095	.133
		30	46.42	1.954	.152	.174	.202	.283
		50	77.36	3.256	.391	.448	.520	.728
		75	116.0	4.884	.828	.949	1.10	1.54
		100	154.7	6.512	1.41	1.62	1.88	2.63
		125	193.4	8.140	2.13	2.44	2.84	3.97
		150	232.1	9.769	2.99	3.43	3.97	5.57
72	6.00	10	15.47	0.547	0.013	0.015	0.017	0.024
		25	38.68	1.368	.071	.081	.094	.132
		50	77.36	2.736	.256	.293	.340	.477
		75	116.0	4.104	.542	.621	.721	1.01
		100	154.7	5.472	.923	1.06	1.23	1.72
		125	193.4	6.840	1.40	1.60	1.86	2.60
		150	232.1	8.208	1.96	2.24	2.60	3.65
		175	270.8	9.576	2.60	2.98	3.46	4.85

The Scobey Formula

Fred C. Scobey,* Senior Irrigation Engineer of the Division of Agricultural Engineering, U. S. Department of Agriculture, offers the following formulas which he says "include viscosity influence for a temperature of 15° C. (59° F.) and differentiate between various types and classes of sheet and plate metal pipe by means of coefficients, which are themselves constant throughout the whole range of sizes and velocities for a given class of pipe":

$$hf = \frac{K_s v^{1.9}}{D^{1.1}}$$

$$v = \frac{hf^{.0526} D^{.58}}{K_s{}^{.0526}}$$

where hf = Loss of head in feet due to friction per 1000 feet of pipe.
D = Mean inside diameter of pipe in feet.
v = Mean velocity of the water in feet per second.
K_s = General coefficient. (K'_s is this value for new pipe.)

Scobey limited his study to pipe of nominal size, four inch and larger, and assumed that the interior of all pipe would be chemically protected with a coating which would form the true interior surface, at least during the first years of the life of the conduit.

He divides sheet and plate metal pipe into three major classes:

Class 1—"Full-riveted" pipe, having both longitudinal and girth seams held by one or more lines of rivets with projecting

*United States Department of Agriculture Technical Bulletin No. 150 "The Flow of Water in Riveted Steel and Analogous Pipes" (1930).

Table 17

Loss of Head in Pipe by Friction for National Duroline Pipe* Calculated by the Hazen-Williams Formula

Pipe size, inches	Average inside diameter, inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (hf) ($c = 148$)
½	0.484	1	1,440	1.74	35.0
		2	2,880	3.48	126.0
		3	4,320	5.23	265.0
		4	5,760	6.97	455.0
		5	7,200	8.72	685.0
		6	8,640	10.46	970.0
		8	11,520	13.95	1650.0
		10	14,400	17.44	2500.0
¾	0.686	2	2,880	1.73	22.8
		3	4,320	2.60	48.0
		4	5,760	3.47	82.0
		5	7,200	4.34	124.0
		6	8,640	5.21	173.0
		8	11,520	6.94	295.0
		10	14,400	8.68	443.0
		15	21,600	13.02	946.0
		20	28,800	17.36	1590.0
1	0.896	3	4,320	1.52	13.2
		4	5,760	2.03	22.2
		5	7,200	2.54	34.5
		6	8,640	3.05	47.5
		8	11,520	4.07	81.0
		10	14,400	5.08	120.0
		12	17,280	6.10	170.0
		14	20,160	7.12	225.0
		16	23,040	8.14	290.0
		20	28,800	10.16	432.0
		25	36,000	12.70	630.0
		30	43,200	15.24	925.0
1¼	1.175	4	5,760	1.18	5.8
		5	7,200	1.47	9.0
		6	8,640	1.77	12.6
		7	10,080	2.07	16.7
		8	11,520	2.36	21.5
		10	14,400	2.95	32.5
		12	17,280	3.55	45.5
		14	20,160	4.14	59.0
		16	23,040	4.73	77.0
		18	25,920	5.32	96.0
1¼	1.175	20	28,800	5.91	116.0
		25	36,000	7.39	175.0
		30	43,200	8.87	245.0
		40	57,600	11.80	420 0
		60	86,400	17.70	880.0
1½	1.405	4	5.760	0.82	2.6(
		5	7,200	1.03	3.95
		6	8,640	1.24	5.2(
		7	10,080	1.44	7.3
		8	11,520	1.65	9.4
		9	12,960	1.86	11.6
		10	14,400	2.06	14.2
		12	17,280	2.48	19.8
		14	20,160	2.89	26.4
		16	23,040	3.31	34.5
		18	25,920	3.72	42.0
		20	28,800	4.13	51.0
		22	31,680	4.55	61.0
		24	34,560	4.96	72 0
		26	37,440	5.38	83.0
		28	40,320	5.79	95.0
		30	43,200	6.20	108.0
		35	50,400	7.24	135.0
		40	57,600	8.27	176.0
		50	72,000	10.34	266.0
		75	108,000	15.51	562.0
		100	144,000	20.69	960.0
2	1.780	6	8,640	0.77	1.66
		8	11,520	1.03	2.82
		10	14,400	1.28	4.20
		12	17,280	1.54	6.0
		14	20,160	1.80	8.0
		16	23,040	2.06	10.2
2	1.780	18	25,920	2.32	12.7
		20	28,800	2.57	15.5
		25	36,000	3.22	23.2
		30	43,200	3.86	33.0
		35	50,400	4.51	44.0
		40	57,600	5.15	56.0
		45	64,800	5.80	77.0
		50	72,000	6.44	84.0
		55	79,200	7.09	100.0
		60	86,400	7.73	117.0
		65	93,600	8.37	135.0
		70	100,800	9.02	157.0
		75	108,000	9.66	177.0
		100	144,000	12.89	302.0
		150	216,000	19.33	570.0
2½	2.182	8	11,250	0.68	1.05
		10	14,400	.85	1.58
		12	17,280	1.02	2.25
		16	23,040	1.37	3.85
		25	36,000	2.14	8.6
		50	72,000	4.29	31.5
		100	144,000	8.58	113.0
		150	216,000	12.87	240.0
		200	288,000	17.16	410.0
		250	360,000	21.45	620.0
3	2.725	10	14,400	0.55	0.54
		15	21,600	.82	1.15
		20	28,800	1.10	1.95
		25	36,000	1.37	2.95
		50	72,000	2.75	10.6
		80	115,200	4.40	25.3
		100	144,000	5.50	38.5
		160	230,400	8.80	90.0
		200	288,000	11.00	136.0
		300	432,000	16.50	290.0
		400	576,000	22.00	500.0
		500	720,000	27.50	750.0
3½	3.205	10	14,400	0.39	0.24
		15	21,600	.59	.52
		20	28,800	.79	.88
		25	36,000	.99	1.34
		50	72,000	1.98	4.8
		80	115,200	3.18	11.5
		100	144,000	3.97	17.5
		160	230,400	6.36	41.5
		200	288,000	7.95	63.0
		300	432,000	11.93	135.0
		400	576,000	15.90	225.0
		500	720,000	19.88	340.0
4	3.620	20	28,800	0.62	0.49
		25	36,000	.77	.74
		30	43,200	.93	1.04
		50	72,000	1.55	2.68
		80	115,200	2.49	6.4
		100	144,000	3.11	9.7
		160	230,400	4.98	23.4
		200	288,000	6.23	35.0
		300	432,000	9.35	72.2
		400	576,000	12.46	124.0
		500	720,000	15.58	187.0
5	4.548	30	43,200	0.59	0.34
		40	57,600	.79	.58
		50	72,000	.98	.87
		80	115,200	1.58	2.10
		100	144,000	1.97	3.15
		160	230,400	3.16	7.7
		200	288,000	3.95	11.5
		300	432,000	5.92	24.2
		400	576,000	7.90	41.2
		500	720,000	9.87	61.8
		750	1,080,000	14.81	131.0
6	5.440	50,000	.0774	0.47	0.20
		60,000	.0928	.57	.26
		80,000	.1238	.76	.44
		100,000	.1547	.95	.66
		140,000	.2166	1.34	1.25
		200,000	.3094	1.91	3.42
		300,000	.4642	2.87	5.2
		400,000	.619	3.83	8.7
		500,000	.774	4.79	13.2
		600,000	.928	5.75	18.5
6	5.440	800,000	1.238	7.67	31.5
		1,000,000	1.547	9.58	48.0
		1,500,000	2,321	14.37	100.0
		2,000,000	3.094	19.17	170.0
8	7.446	200,000	.3094	1.02	0.53
		300,000	.4642	1.53	1.12
		360,000	.557	1.84	1.57
		400,000	.619	2.04	1.92
		500,000	.774	2.55	2.88
		600,000	.928	3.06	4.05
		700,000	1.083	3.58	5.4
		800,000	1.238	4.09	6.9
		900,000	1.392	4.60	8.6
		1,000,000	1.547	5.11	10.5
		1,200,000	1.857	6.13	14.6
8	7.356	200,000	.3094	1.04	0.56
		300,000	.4642	1.57	1.18
		400,000	.619	2.09	2.00
		500,000	.774	2.62	3.05
		600,000	.928	3.14	4.30
		700,000	1.083	3.66	5.7
		800,000	1.238	4.19	7.3
		1,000,000	1.547	5.24	11.2
		1,500,000	2.321	7.86	23.8
		2,000,000	3.094	10.48	40.0
		3,000,000	4.642	15.72	84.0
10	9.443	300,000	.4642	0.95	0.35
		400,000	.619	1.27	.60
		500,000	.774	1.59	.90
		600,000	.928	1.90	1.26
		750,000	1.160	2.38	1.92
		1,000,000	1.547	3.18	3.25
		1,500,000	2.321	4.77	6.9
		2,000,000	3.094	6.36	11.8
		3,000,000	4.642	9.54	25.0
		4,000,000	6.188	12.72	42.5

*Pipe lined with a highly resistant cement-base composition lining.—Ed.

heads. From the capacity standpoint, pipe with countersunk rivet heads on the interior belong in *Class* 3.

Class 2—"Girth-riveted" pipe, having no retarding rivet heads in the longitudinal seams, but having the same girth seams as full-riveted pipe.

Class 3—"Continuous-interior" pipe, having the interior surface unmarred by plate offsets or by projecting rivet heads in either longitudinal or girth seams. Not necessarily described as "smooth."

For these classes Scobey suggests the following coefficients for new pipe:

Class 1*a*, $K'_s = 0.38$ for new sheet metal pipe up to three-sixteenths of an inch thick.

Class 1*b*, $K'_s = 0.44$ for new plate metal pipe on three-sixteenths to seven-sixteenths of an inch thick, with either taper or cylinder joints.

Class 1*c*, $K'_s = 0.48$ for new plate metal pipe from one-half inch up, with either taper or cylinder joints, and for plate from one-fourth to seven-sixteenths of an inch thick when butt-jointed.

Class 1*d*, $K'_s = 0.52$ for new butt-strap pipe of plate from one-half inch up.

Class 2*d*, $K'_s = 0.34$ for new girth-riveted pipe. This includes all sheet and plate metal pipe with continuous seamed lognitudinal joints but with girth joints, particularly field joints, made with the usual rivet heads inside the pipe.

Class 3, $K'_s = 0.32$ for new continuous-interior pipe. This class comprises all type of sheet and plate metal pipe that offer a practically uniform interior surface of relative smoothness. "Continuous-interior" is offered as descriptive of an interior surface unbroken by rivet heads or appreciable shell-thickness offsets. Use of the apparently obvious synonym "smooth" has purposely been avoided, as this description might hold only while the pipe is new.

NOTE: Although Scobey confines his paper to the discussion of sheet and plate metal pipe, *Classes* 2 and 3 also apply to seamless pipe as well as to lap-weld, hammer-weld, and electric-weld pipe.

It should be noted that the coefficients (K'_s) given above

are for new pipe. Concerning the deterioration of carrying capacity with age, Scobey states:

"It has long been appreciated that all metal pipe deteriorates in carrying capacity; the rate of decrease being dependent on the efficiency of the pipe coating, the composition and treatment of the pipe material, and the activity of the water conveyed in the pipe. Filtered and treated water causes less deterioration than raw water. Long lines deteriorate more rapidly at the upper ends than at the lower ends. "So far as available data indicate, the increase in the value of K_s with age, is expressed by the formula:

$$K_s = K'_s e^{0.015t}$$

where e = Base of Naperian logarithms (2.7183).
t = Age of pipe in years.
When t is zero, then K_s becomes K'_s."

[NOTE: Tables showing various values of K_s and corresponding losses of head at various velocities and also values of $v^{1.9}$ have had to be omitted. For a copy of these address National Tube Co., Pittsburgh, Pa., asking for Technical Bulletin No. 21. —Ed.]

Fig. 36, which was taken from United States Department of Agriculture Technical Bulletin No. 150, will be found useful in making estimates and preliminary studies. It gives the relation between discharge, pipe diameter, velocity, and loss of head for various values of the coefficient K_s. Values of K_s for ages of 0 to 50 years corresponding to various values of K'_s are also given.

The lower age diagram on the chart is based on the formula $K_s = K'_s e^{0.115t}$ and is to be used for aggressive waters. The upper age diagram is based on the formula $K_s = K'_s e^{0.01t}$ and is intended for use where the waters are known to be non-aggressive.

The following example will illustrate the method of using this chart:

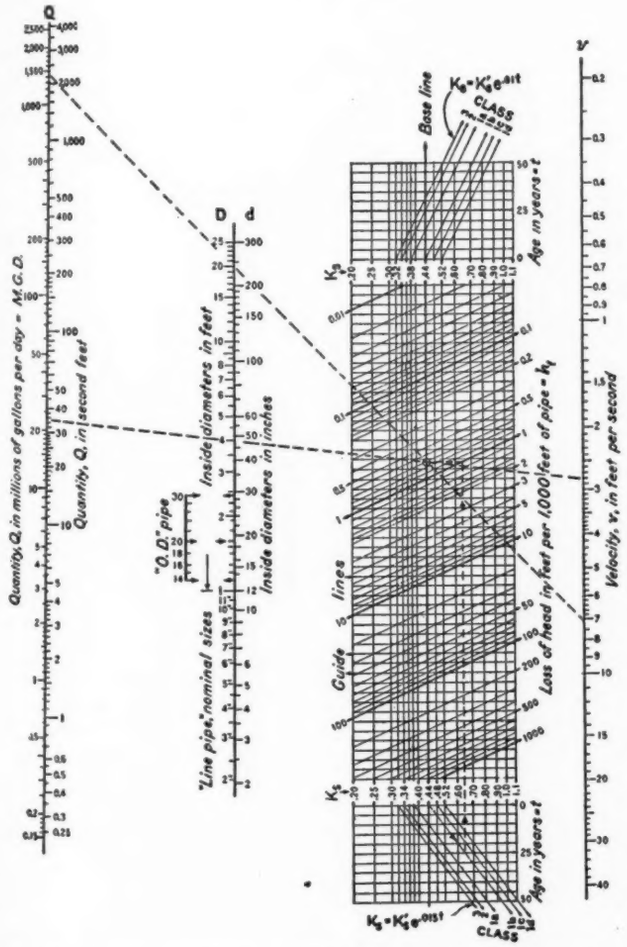

Q
D d
Base line
Guide lines
Quantity, Q, in millions of gallons per day = M.G.D.
Quantity, Q, in second feet
Inside diameters in feet
Inside diameters in inches
"Line pipe," nominal sizes
"O.D." pipe
Loss of head in feet per 1,000 feet of pipe = h_f
Velocity, v, in feet per second
Age in years = t
CLASS

Fig. 36 — Chart Showing Relation Between Discharge Pipe Diameter, Velocity, and Loss of Head for Various Values of the Coefficient K_s and K_{s1} in Scobey Formula

Table 21

Special Losses of Head in Terms of $v^2/2g$ (From Hydraulics, by Ernest W. Schoder and Francis M. Dawson—Second Edition, 1934, with Modifications)

Nature of special resistance	Loss of head as decimal or multiple of $v^2/2g$*
Entrance	
Square-edged entry. Upstream end of pipe perpendicular to, and flush with inside face of reservoir wall	0.50
Projecting pipe at entry or re-entrant pipe end	1.00
Well-rounded entry	0.02 to 0.05
Curves and Fittings	
Easy curves or bends of very large radius, and smooth inside, of same inside diameter throughout as the pipe line.	
Excess loss over same length of straight pipe	0.05 to 0.15
90-degree curves, fairly smooth, same inside diameter as pipe;	
Radius of center line = diameter of pipe	0.50
Radius of center line = 2 to 8 times diameter of pipe	0.25
90-degree common screw end pipe elbows, short turn, inside larger than pipe	0.75
Tees, common screw end, full-size branch, flow deviated 90 degrees	1.50
Square elbow (intersection of two cylinders, corner not rounded at outside or inside of curve.)	1.25
Obtuse-angled elbows, (deflection of pipe less than 90 degrees); multiply values for square elbow or 90-degree curve by $\left(\frac{\text{deflection, degrees}}{90 \text{ degrees}}\right)^2$	
Water Meters (Subject to much variation)	
Disk or "wobble-disk" type	3.4 to 10
Rotary type (star or cog-wheel-shaped disk as piston)	10
Reciprocating piston type (like a piston pump)	15
Turbine-wheel type (double flow, balanced)	5 to 7.5
Diaphragm and Orifice Meters	
Diaphragm of thin material across pipe, with concentric hole, or an inside projecting washer or gasket, or a "burr", due to cutting pipe with a wheel cutter:	
Diameter of hole = 0.91 × diameter of pipe	0.34
Diameter of hole = 0.80 × diameter of pipe	1.88
(Note that $v^2/2g$ in this particular case refers to pipe, not to the area of opening, nor to the contracted stream through opening.)	
Nozzles	
Nozzles: when the coefficient of velocity and discharge ranges from 0.99 to 0.975, the loss of head ranges from	0.02 to 0.05 (Where v is the velocity of the issuing jet)

*Note: Except where otherwise noted, v is the mean velocity in the pipe.

Assume that it is desired to know what conditions will prevail in a pipe line constructed of full-riveted pipe (*Class* 1*b*) after carrying aggressive waters for a period of 25 years.

From page 45 the coefficient K_s for new pipe of *Class* 1*b* is found to be 0.44. On the lower age diagram follow the diagonal line representing $K_s = 0.44$ (at 0 age) until it intersects the horizontal line representing an age of 25 years. From this point of intersection proceed vertically on the dashed line (which represents $K_s = 0.64$) until it intersects the slope line of 1 foot per 1000 feet of pipe. From this point follow the guide lines to the vertical base line. Using this point (marked on the chart by a circle) as a pivot, a straight edge will give simultaneous values of discharge (Q) diameter (D or d) and velocity (v). This is illustrated by dashed lines for 20 feet and 4 feet inside diameter pipe. The dashed line through the pivot point and the point representing pipe of 20 feet inside diameter shows that a discharge of 2250 cubic feet per second and a velocity of 7.2 feet per second can be expected. The other dashed line through the pivot point and through the point representing pipe 4 feet inside diameter indicates a discharge of 36 cubic feet per second and a velocity of 2.8 feet per second.

Special Losses of Head

Curves, elbows, tees, meters, enlargements, contractions, etc., in a pipe line cause losses of head, which, if of consequence, must be allowed for in addition to the loss of head ordinarily encountered in straight pipe of uniform cross section.

Special losses may be expressed as equivalent lengths of straight pipe which would cause the same loss of head, or as decimals or multiples of $v^2/2g$, where v is the mean velocity in the pipe. For any particular special fittings, experiments show that the loss of head is not in all cases a constant fraction of

Table 21—Concluded

Special Losses of Head in Terms of $v^2/2g$

Nature of special resistance	Loss of head as decimal or multiple of $v^2/2g$*
Venturi Meter Tubes	
Venturi meter tubes: the loss of head occurs mostly in and downstreamwards from the divergence, the loss between upstream end and throat being only 0.03 to $0.06 \times v^2/2g$, where v is the throat velocity. The total loss through the meter is:	
For total angle of divergence = ±5 degrees	$\frac{1}{7}$ to $\frac{1}{10}$ } Where v is the throat velocity
For total angle of divergence = ±15 degrees	$\frac{1}{3}$ to $\frac{1}{6}$ }
(The lower values go with large throats, and the larger values with small throats whose diameter is from ⅓ to ½ the diameter of the pipe.)	
Sudden Enlargement	
Sudden enlargement, from a small pipe ending abruptly where a larger pipe begins, is found to involve loss of head fairly close in accordance with Borda's Formula which is: Loss of head $= \frac{(v_1 - v_2)^2}{2g}$ (Note that this is not the difference of the velocity heads, but is the head corresponding to the difference of the velocities.) The above-stated formula may be written: Loss of head $= \left(1 - \frac{A_1}{A_2}\right)^2 \frac{v_1^2}{2g}$, or for a circular or square pipe: Loss of head $= \left[1 - \left(\frac{d_1}{d_2}\right)^2\right]^2 \times \frac{v_1^2}{2g}$ where A_1, v_1 and d_1 refer to the smaller upstream pipe, while the subscript 2 refers to the larger downstream pipe.	
Sudden Square-Edged Reductions	
Sudden square-edged reductions in pipes. When the sudden reduction of pipe is very large, say $d_2/d_1 = 0.1$, the loss of head is practically as given for square-edged entry, i.e., loss of head $= 0.40\, v_2^2/2g$. For smaller reductions the value of K is smaller, but the experimental data of Weisbach (1855) and Brightmore (1907) do not agree. For ratios $d_2/d_1 =$ 0.5, 0.75, and 0.9 the value K is about 0.33, 0.20 and 0.08, respectively. In this case the subscript 2 refers to the smaller downstream pipe, and K is the factor which, multiplied by $v_2^2/2g$, gives the loss of head.	

*Note: Except where otherwise noted, the v is mean velocity in the pipe.

$v^2/2g$, but that the fraction varies somewhat with the velocity. For most practical purposes, however, the values given in 21 may be relied on as safe average values.

Water Hammer

When a valve in a water line is closed while the water is flowing, the velocity of the water upstream from the valve is reduced and a dynamic pressure is exerted in addition to the normal static pressure. This dynamic pressure, commonly called "water hammer," is the result of the transformation of the kinetic energy of the moving mass of water into pressure energy which expends itself (unless relief devices are provided) by compressing the water and stretching the pipe walls. When a valve is closed suddenly, the magnitude of the dynamic pressure produced is frequently much greater than the static pressure on the line, and may cause fracture of the pipe or fittings.

Starting at the suddenly-closed valve, a wave of increased pressure is transmitted back through the pipe with constant velocity and intensity. When the pressure wave has traveled upstream to the end of the pipe, where there is a reservoir or large main, the elasticity of the compounded water and of the expanded pipe reverse the flow and a wave of normal pressure travels downstream, the flow being progressively reversed as the water expands.

If the water were incompressible and the pipe inelastic, the instantaneous closure of the valve would create an infinite pressure. Since it is impossible to close a valve instantaneously, it is apparent that a series of pressure waves is created, causing an increased pressure at the valve. If the valve is completely closed before the first pressure wave has time to return to the valves as a wave of low pressure, the pressure increases continually up to the time of complete closure and the resulting pressure is just the same as if the valve had been instantaneously closed. The velocity of the pressure wave depends upon the ratio of wall-thickness to inside pipe diameter and on the modulus of elasticity of the water and of the pipe material according to the formula:

$$S = \frac{12}{\sqrt{\frac{w}{g}\left(\frac{1}{E_w} + \frac{d}{E_p t}\right)}}$$

The head due to water hammer in excess of normal static head is proportional to the destroyed velocity and to the velocity of the pressure wave along the pipe. Since the intensity of the excess head depends upon the destroyed velocity, the same excess pressure is produced by suddenly reducing the velocity from 6 to 3 feet per second, as by entirely stopping a velocity of 3 feet per second. The excess head due to water hammer is given by the formula:

$$h = \frac{12\, v}{g\sqrt{\frac{w}{g}\left(\frac{1}{E_w} + \frac{d}{E_p t}\right)}}$$

where S = Velocity of pressure wave along pipe in feet per second.
w = Weight of water in pounds per cubic foot.
h = Head due to water hammer (in excess of static head).
g = Acceleration of gravity.
t = Wall-thickness of pipe in inches.
d = Inside diameter of pipe in inches.
E_p = Modulus of elasticity of pipe material in pounds per square inch.
E_w = Modulus of elasticity of water in pounds per square inch.
v = Destroyed velocity in feet per second.

By inserting values for g, w, E_w and E_p the two formulas may be simplified. Thus, if
$g = 32.174$ feet per second per second.
$w = 62.4096$ pounds per cubic foot (at 50° F.)
$E_w = 300{,}000$ pounds per square inch.
$E_p = 29{,}000{,}000$ pounds per square inch (for steel pipe)
the formulas reduce to:

$$S = \frac{4720}{\sqrt{1 + .0103\frac{d}{t}}}$$

$$h = \frac{147\, v}{\sqrt{1 + .0103\frac{d}{t}}}$$

If the flow is not checked rapidly, so that the wave from the first movement of the valve has time to travel upstream to the end and back again several times while the valve closing is in progress, the excess pressure is greatly reduced. Therefore, it is advisable to use slow closing valves or to provide air chambers or surge tanks in the line to absorb the shock due to water hammer.

Measurement of Flowing Water

Pitot Tubes

Pitot tubes are used to measure the velocity of flowing water. Such a tube consists essentially of a vertical tube, the lower end of which is bent at 90° so that its open end is directed against the current. The velocity of the flowing water causes the water to rise in the vertical leg of the pitot tube a distance above the free surface of the stream equal to the velocity head.

When a pitot tube is inserted into a pipe carrying water under pressure, the water will rise in the vertical leg of the tube a distance equal to the sum of the pressure head and the velocity head at the point where the tube is inserted. If a piezometer tube is tapped into the wall of the pipe at substantially the same point, the water will rise in this tube a distance equal to the pressure head at that point. The difference in the levels of the water in the two tubes will therefore be equal to the velocity head in the pipe at the point where the tubes are inserted. Fig. 37 shows such an arrangement. The height of the water in the pitot tube is equal to the sum of the pressure head, h_p, and the velocity head, h_v. The height of the water in the piezometer tube is equal to the pressure head, h_p. The

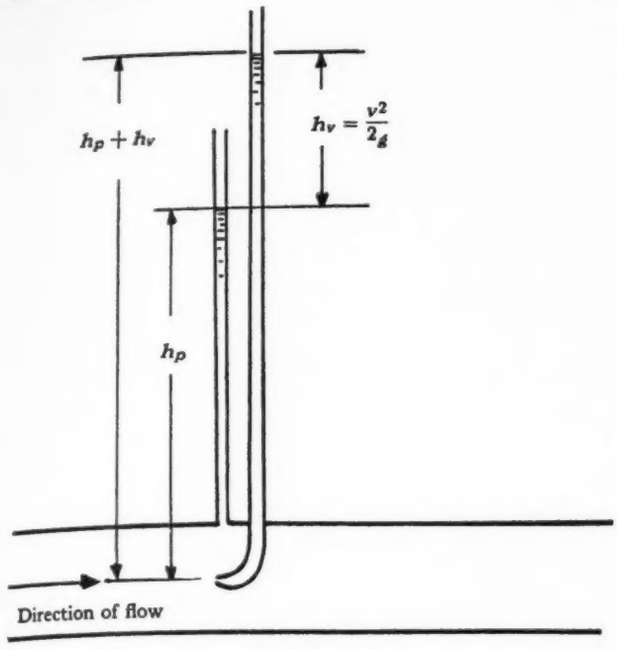


Fig. 37—Pitot Tube

difference in the height of the water in the two tubes is therefore equal to the velocity head, h_v.

Mercury columns or manometers may be used, instead of the water column, to determine the pressures.

In order to determine the discharge by use of a pitot tube, the cross section of the stream or pipe must be divided into one or more known areas, the velocity for each found, and hence the mean velocity of the entire cross section. The discharge is then found by multiplying the cross-sectional area by the mean velocity. In a straight length of pipe which extends upstream about 50 diameters from place of measurement without tees, valves, etc., the distribution of velocities is normal. Where normal distribution of velocities prevails, the ratio of mean velocity to center velocity (called the pipe coefficient) averages about 0.83.

Venturi Meters

The Venturi meter was invented by Clemens Herschel and was named by him for the inventor of the principle involved. It may be used to measure the discharge of water or other fluids contained in pipes which run full and under positive pressure.

The Venturi tube consists of a converging cone of steep taper, a diverging cone of more gradual taper, and a short cylindrical section called the throat, which connects the two cones at their smallest diameters. The essential parts of a Venturi meter are shown in Fig. 38. In this figure h_1 represents the pressure head in the pipe upstream for the Venturi meter, h_2 the pressure head at the throat, and h_3 the pressure head in the pipe downstream from the Venturi meter. The difference between h_1 and h_3 is hf and is the loss of head due to friction in the Venturi tube. The loss of head in a Venturi tube is usually quite small (see Table 21). Where the recovery of pressure is not important the converging cone may be very short or may even be omitted, forming a Venturi nozzle.

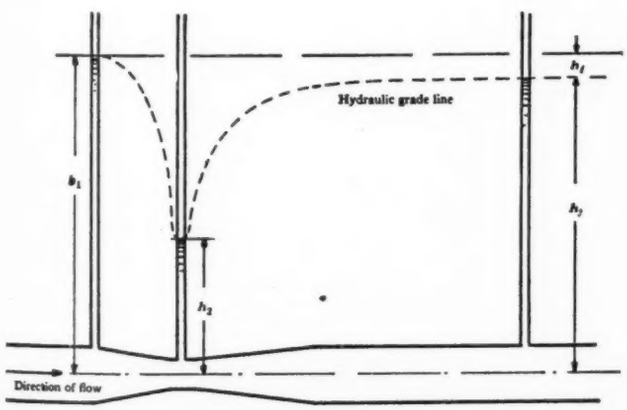


Fig. 38—Venturi Meter

Since the quantity of water flowing past any cross section of the tube is the same at any instant, the velocity at the small cross section of the throat will be greater than in the large cross section of the pipe upstream from the Venturi tube.

This greater velocity in the throat is obtained at the expense of the pressure head, so that h_2 is less than h_1. The dotted line in the figure represents the approximate hydraulic grade line and indicates the loss and recovery of pressure from h_1 to h_2.

The relation between the flow through a Venturi tube and the difference in pressure between the inlet and throat is given by the formula:

$$Q = C_v A_2 \sqrt{\frac{2ghd}{1-\left(\frac{A_2}{A_1}\right)^2}} = C_v A_2 \sqrt{\frac{2ghd}{1-\left(\frac{D_2}{D_1}\right)^4}}$$

where Q = Discharge in cubic feet per second.
D_1 = Inside diameter of pipe in feet.
D_2 = Inside diameter of throat of Venturi tube in feet.
A_1 = Cross-sectional area of inside of pipe in square feet.
A_2 = Cross-sectional area of inside of throat of tube in square feet.
g = Acceleration of gravity = 32.174 feet per second per second.
hd = Differential head in feet of water = $h_1 - h_2$.
C_v = Discharge coefficient of Venturi tube which varies from about 0.95 to 0.995.

The pressure differences ($h_1 - h_2$) may be measured by a simple glass U-tube containing mercury. Commercial Venturi tubes are usually provided with two annular chambers connected by vents with the inlet and throat, respectively, to obtain correct average pressures at these points. Various types of indicating, recording and integrating meters may be obtained for use with commercial Venturi tubes.

Pipe Orifices

Orifices in diaphragms inserted between pairs of flanges in straight portions of pipe lines have been found to be reliable measuring devices. The diaphragms are usually of thin noncorrodible metal and the orifices are accurately machined to size and beveled on the downstream side to keep the working edge thin.

Fig. 39 shows the essential parts of such a device. Two piezometer tubes are attached to the line, one at a distance of

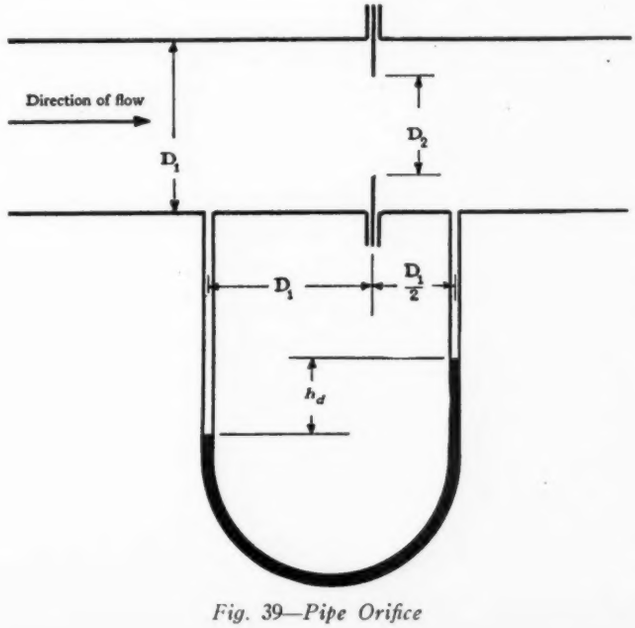


Fig. 39—Pipe Orifice

one pipe diameter upstream and the other one-half pipe diameter downstream from the plate. Either a differential gage, as shown in the figure, or open water columns may be used, depending upon the pressure. The rate of flow is a function of the differential pressure as indicated by the formula:

$$Q = C_o A_2 \sqrt{\frac{2ghd}{1-\left(\frac{A_2}{A_1}\right)^2}} = C_o A_2 \sqrt{\frac{2ghd}{1-\left(\frac{D_2}{D_1}\right)}}$$

where Q = Discharge in cubic feet per second.
D_1 = Inside diameter of pipe in feet.
D_2 = Diameter of orifice in feet.
A_1 = Cross-sectional area of inside of pipe in square feet.
A_2 = Cross-sectional area of orifice in square feet.
g = Acceleration of gravity = 32.174 feet per second per second.
hd = Differential head in feet of water = $h_1 - h_2$.
C_o = Discharge coefficient = about 0.606 for D_2/D_1 from 0.10 to 0.75.

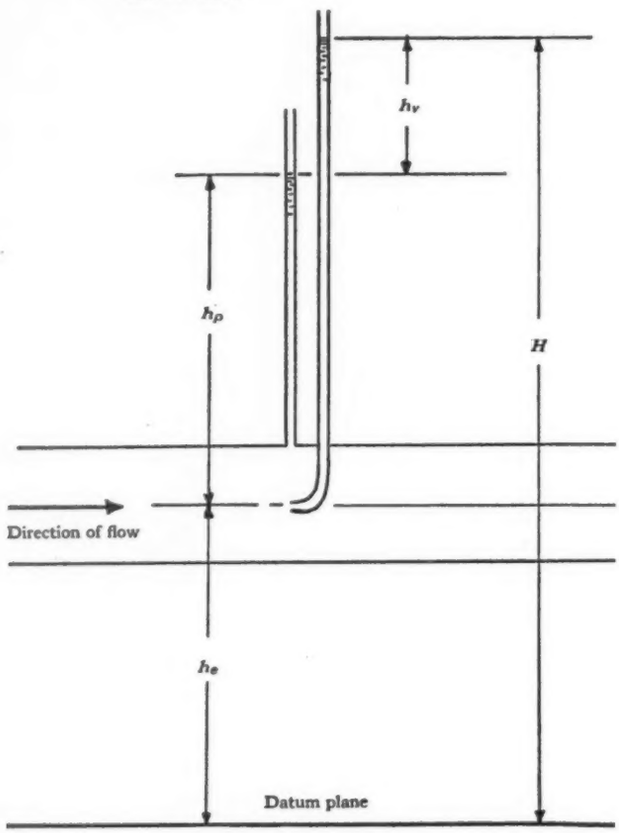


Fig. 40—Total Head

The orifice should be placed in a straight section of horizontal or vertical pipe and should be located as far as possible from bends, fittings, and valves. The diameter of the orifice should not be greater than 75 to 80 per cent of the inside diameter of the pipe. The loss of head in the pipe orifice is quite large and it is less reliable than the Venturi meter.

Water Power

The total available power of flowing water is given by the formula:

$$H.P. = \frac{QwH}{550} = 0.113472\,QH$$

where $H.P.$ = Horse Power.
Q = Discharge in cubic feet per second.
H = Total available head in feet.
w = Weight of one cubic foot of water (at 50° F. = 62.4096 pounds).

The total head may be made up of velocity head, pressure head, and potential head, or head due to actual height above the datum plane. Fig. 40 illustrates the three components of the total head.

The value of the velocity head is given by the expression:

$$h_v = \frac{v^2}{2g}$$

where h_v = Velocity head in feet.
v = Mean velocity in feet per second.
g = Acceleration of gravity = 32.174 feet per second per second.

Table 22
Horsepower for Various Heads of Water

Horse power for 1 cu. ft. of water per second under heads of 1 to 2,000 ft. Based on an efficiency of 80 per cent and weight of water at 50°F. = 62.4096 lb. per cubic foot.

(Horse power per cubic foot of water per second = $\frac{62.4096 \times 0.80 \times H}{550} = 0.0907776\,H$).

Head in feet (H)	Horse power	Head in feet (H)	Horse power	Head in feet (H)	Horse power	Head in feet (H)	Horse power
1	0.0907776	170	15.4322	420	38.1266	925	83.9693
2	.181555	180	16.3400	430	39.0344	950	86.2387
3	.272333	190	17.2477	440	39.9421	975	88.5082
4	.363110	200	18.1555	450	40.8499	1000	90.7776
5	.453888	210	19.0633	460	41.7577	1050	95.3165
6	.544666	220	19.9711	470	42.6655	1100	99.8554
7	.635443	230	20.8788	480	43.5732	1150	104.394
8	.726221	240	21.7866	490	44.4810	1200	108.933
9	.816998	250	22.6944	500	45.3888	1250	113.472
10	.907776	260	23.6022	525	47.6582	1300	118.011
20	1.81555	270	24.5100	550	49.9277	1350	122.550
30	2.72333	280	25.4177	575	52.1971	1400	127.089
40	3.63110	290	26.3255	600	54.4666	1450	131.628
50	4.53888	300	27.2333	625	56.7360	1500	136.166
60	5.44666	310	28.1411	650	59.0054	1550	140.705
70	6.35443	320	29.0488	675	61.2749	1600	145.244
80	7.26221	330	29.9566	700	63.5443	1650	149.783
90	8.16998	340	30.8644	725	65.8138	1700	154.322
100	9.07776	350	31.7722	750	68.0832	1750	158.861
110	9.98554	360	32.6799	775	70.3526	1800	163.400
120	10.8933	370	33.5877	800	72.6221	1850	167.939
130	11.8011	380	34.4955	825	74.8915	1900	172.477
140	12.7089	390	35.4033	850	77.1610	1950	177.016
150	13.6166	400	36.3110	875	79.4304	2000	181.555
160	14.5244	410	37.2188	900	81.6998	....	.....

Table 25—Pressure Equivalents

Units		Pounds per square inch	Pounds per square foot	Kilograms per square centimeter	Inches of mercury at 32° F.	Feet of water at 39.2° F.	Feet of water at 62° F.	Atmospheres
1 pound per square inch	=	1.	144.	0.0703067	2.0360	2.30671	2.30934	0.068044
1 pound per square foot	=	0.0069444	1.	0.0004882	0.014139	0.016019	0.016037	0.0004725
1 ounce per square inch	=	0.0625	9.	0.0043942	0.12725	0.144169	0.144334	0.0042528
1 kilogram per square centimeter	=	14.2234	2048.17	1.	28.9582	32.8092	32.8467	0.967820
1 kilogram per square meter	=	0.0014223	0.204817	0.0001	0.0028958	0.0032809	0.0032847	9.678×10^{-5}
1 inch of mercury at 32° F.	=	0.49117	70.7285	0.034533	1.	1.13299	1.13428	0.033421
1 inch of water at 39.2° F.	=	0.036127	5.20222	0.0025399	0.073552	0.083333	0.083428	0.0024582
1 inch of water at 62° F.	=	0.036085	5.19628	0.0025370	0.073468	0.083238	0.083333	0.0024554
1 foot of water at 39.2° F.	=	0.43352	62.4266	0.030479	0.88262	1.	1.00114	0.029498
1 foot of water at 62° F.	=	0.43302	62.3554	0.030444	0.88162	0.99886	1.	0.029465
1 atmosphere	=	14.6963	2116.27	1.03325	29.9210	33.9001	33.9388	1.

Table 26—Rate of Flow Equivalents

Units		Cubic feet per second	Cubic feet per minute	U. S. gallons per minute	U. S. gallons per 24 hours	British Imperial gallons per minute	Liters per minute	Acre-feet per hour	Acre-feet per 24 hours
1 cubic foot per second	=	1.	60.	448.831	646 317.	373.729	1698.98	0.082645	1.98347
1 cubic foot per minute	=	0.016667	1.	7.48052	10 771.9	6.22882	28.3163	0.0013774	0.033058
1 U. S. gallon per minute	=	0.0022280	0.13368	1.	1440.	0.83267	3.78533	0.0001841	0.0044192
1 U. S. gallon per 24 hours	=	1.547×10^{-6}	9.283×10^{-5}	0.0006944	1.	0.0005782	0.0026287	1.279×10^{-7}	3.069×10^{-6}
1 British Imperial gallon per minute	=	0.0026757	0.16054	1.20095	1729.37	1.	4.54601	0.0002211	0.0053072
1 liter per minute	=	0.0005886	0.035315	0.26418	380.416	0.21997	1.	4.864×10^{-5}	0.001167
1 acre-foot per hour	=	12.1	726.	5430.86	7 820 434.	4522.13	20 557.6	1.	24.
1 acre-foot per 24 hours	=	0.50417	30.25	226.286	325 851.	188.422	856.567	0.041667	1.

Table 26—Volume and Capacity Equivalents

Units		United States gallons	British Imperial gallons	Liters	Cubic feet	Cubic inches	Acre-feet
1 United States gallon	=	1.	0.832672	3.78533	0.133681	231.	3.069×10^{-6}
1 British Imperial gallon	=	1.20095	1.	4.54601	0.160544	277.420	3.686×10^{-6}
1 liter	=	0.264177	0.219973	1.	0.035315	61.0250	8.107×10^{-7}
1 cubic foot	=	7.48052	6.22882	28.3163	1.	1728.	2.296×10^{-5}
1 cubic inch	=	4.329×10^{-3}	3.605×10^{-3}	0.016387	5.787×10^{-4}	1.	1.329×10^{-8}
1 acre-foot	=	325 851.	271 328.	1 233 456.	43 560.	75 271 680.	1.
1 inch deep on 1 acre	=	27 154.3	22 610.6	102 788.	3 630.	6 272 640.	0.083333
1 inch deep on 1 square mile	=	17 378 743.	14 470 801.	65 784 344.	2 323 200.	4 014 489 600.	53.3333
1 meter deep on 1 hectare	=	2 641 705.	2 199 675.	9 999 734.	353 145.	610 233 780.	8.10708
1 centimeter deep on 1 square meter	=	2.64171	2.19967	9.99973	0.353145	610.234	8.107×10^{-6}
1 pound of water at 39.2° F.	=	0.11983	0.099778	0.45359	0.016019	27.6805	3.677×10^{-7}
1 pound of water at 50° F.	=	0.11986	0.099806	0.45372	0.016023	27.6880	3.678×10^{-7}
1 pound of water at 62° F.	=	0.11997	0.099892	0.45411	0.016037	27.7121	3.682×10^{-7}
1 U. S. gallon per minute for 24 hours	=	1440.	1199.05	5450.88	192.5	332 640.	0.0044192
1 cubic foot per minute for 24 hours	=	10 771.9	8 969.50	40 775.4	1440.	2 488 320.	0.033058

The pressure head is given by the expression:

$$h_p = \frac{P}{w}$$

where h_p = Pressure head in feet.
P = Pressure in pounds per square foot.

The potential head or head due to height above the datum plane is h_e feet.

The total head, H, is therefore:

$$H = h_v + h_p + h_e$$

or

$$H = \frac{v_2}{2g} + \frac{P}{w} + h_e$$

In any stream flowing steadily without friction, the total head, and the total amount of energy per unit of water, is the same at every point in the path of flow. This principle, which is in reality the law of conservation of energy applied to flowing water, is known as Bernoulli's Theorem.

Table 22 gives the horse power for one cubic foot of water per second, under heads of 1 to 2000 feet, based on an efficiency of 80 per cent. The method of using this table is illustrated by the following example:

Determine the horse power which can be developed by a flow of 60 cubic feet per second under a head of 200 feet.

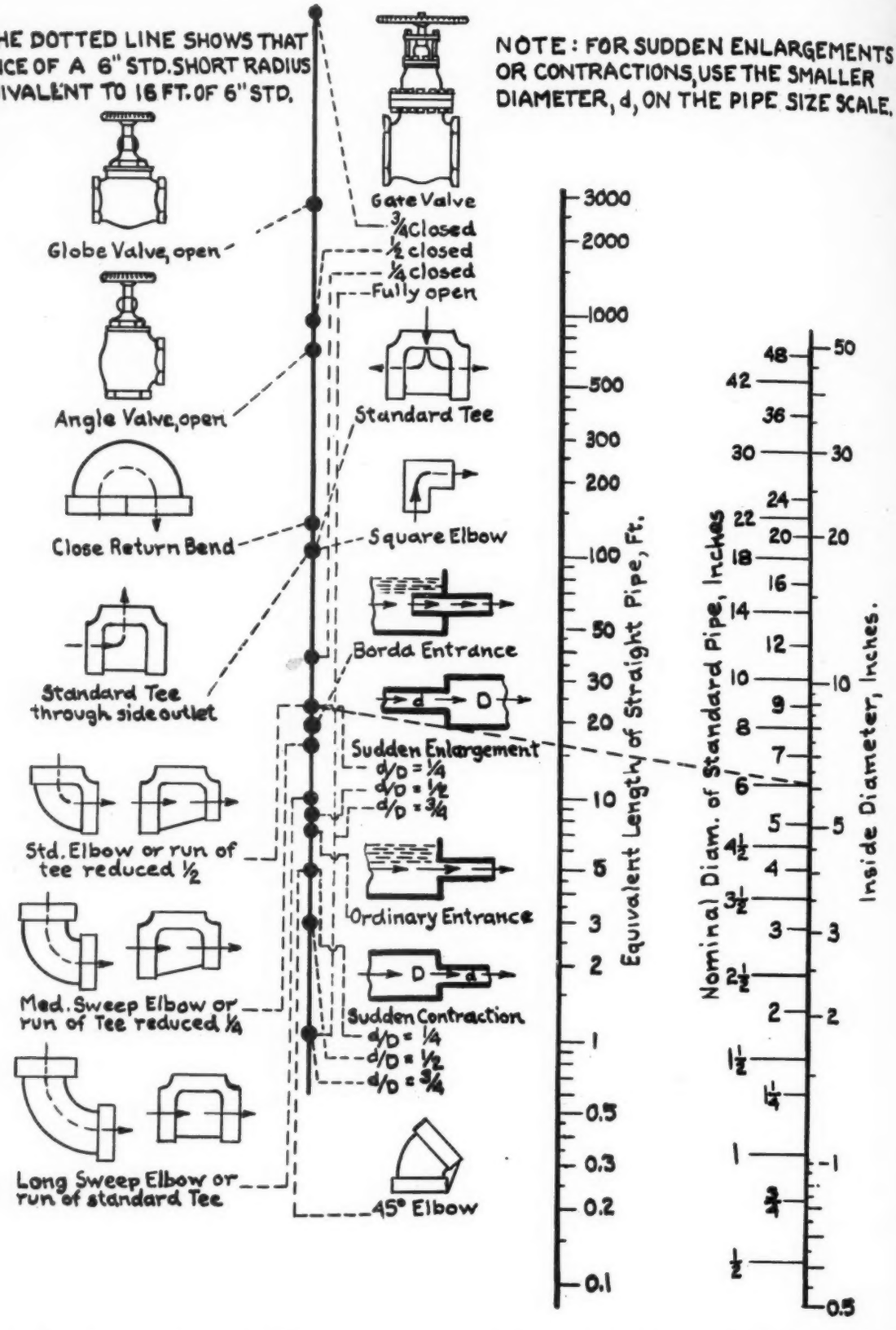
From the table the horse power for a discharge of one cubic foot per second under 200 feet head is found to be 18.1555. The horse power for a discharge of 60 cubic feet per second under 200 feet head is then:

$$60 \times 18.1555 = 1089.33 \text{ horse power.}$$

When the exact head is not given in the table the horse power may be found by multiplying the horse power for one foot head and one cubic foot per second (0.0907776) by the head in feet and then by the discharge in cubic feet per second. For example, the horse power which can be developed by a discharge of 45 cubic feet per second under a head of 105 feet will be:

$$0.0907776 \times 105 \times 45 = 428.92 \text{ horse power.}$$

RESISTANCE OF VALVES AND FITTINGS TO FLOW OF WATER*



When the flow of a fluid in a pipe line is altered by some obstruction such as a valve or fitting, the velocity is changed, turbulence is magnified and a drop in pressure results. This pressure drop may be insignificant in long lines where it is very small in comparison to the total drop, but when the line is short the pressure drop through valves and fittings becomes

a major item in the total pressure drop value.

The most widely used data on the subject of the resistance of valves and fittings to the flow of water and steam is the information given in Dean Foster's paper on "Effect of Fittings on Flow of Fluids Through Pipe Lines" published in Vol. 42, 1920, of the Transactions of the American Society of Mechanical Engineers. Recently, tests conducted by others have indicated that the values given by Foster are low for globe valves, angle valves, etc., and that data is needed to establish the correct information to use. It has been the tendency, and probably is the most practical way, to present the friction values in terms of an equivalent length of the same size of pipe; i.e., the pressure drop caused by a 2-inch elbow is equivalent to approximately the pressure drop caused by five or six feet of 2-inch pipe under the same conditions of flow.

Realizing the need for definite data covering this subject, Crane Co. has recently conducted pressure drop tests on valves and fittings on both water and steam. These tests were made on 2 inch and 6 inch sizes and conducted under conditions which were thoroughly investigated previous to the tests. The results of these tests are presented herewith together with a description of the method used in conducting them.

[*Note.*—Water and steam can be treated comparatively and a relation can be established between the relative friction values of water and steam. Foster has stated that the equivalent length of pipe for steam flow is about .8 of that established for the flow of water.]

Friction Losses of Water Line Valves and Fittings

The tests for determining the pressure drop of valves and fittings installed in a water line were made in the following manner:

A flow nozzle was installed in a 3 in. test line leading from the bottom of a 1,000 gallon water tank. A mercury manometer was set across this nozzle and the relation of mercury deflection to the gallons of water per minute flowing through the pipe was determined. The flow through the pipe was thereafter noted only in terms of mercury deflection which was readily transposed into gallons per minute by reference to the calibration chart.

The valve or fitting to be tested was placed in the line at some distance from the flow nozzle and the flow water through it was regulated by a throttling valve situated at the outlet of the line. The pressure drop was measured by means of a mercury manometer, or where the deflection was too great, by two sensitive low pressure gages, the leads of which were situated in the test line at a distance of ten pipe diameters (20 in.) from each end of the valve or fitting on test. The initial pressure at the inlet of the test line was kept constant at 80 pounds per square inch and the various rates of flow produced by throttling the outlet of the test line.

After the data was obtained the means of presenting it in its best form was investigated. In any pressure drop tabulation, the values for the fittings and valves in the line are added to the pressure drop of the entire length of line. Therefore, it seemed reasonable to disregard the pressure drop caused by the length of the valve or fitting and just list the pressure drop which was added to the line due to the presence of the article.

For instance, if a valve 4 in. face to face is installed in a line 30 in. long, the actual pressure drop through the valve will be the total pressure drop minus the pressure drop caused by 26 in. of pipe. However, in a practical problem this value will be added to the pressure drop caused by the total length of the line which will give a pressure drop value slightly higher than the actual. This may not be so noticeable with one or two valves or fittings in the line, but where the number runs up into 10 or 20 the added drop may be considerable.

This "No-length" concept was established and has been used before with reference to elbows in "The Friction of Water in Pipes and Fittings" by F. E. Giesecke, University of Texas Bulletin No. 1759.

Resistance in Terms of Equivalent Pipe Length

From data given in the tests conducted by Crane Co. and also from information gathered from authentic sources, Fig. 16, has been prepared which gives the equivalent length of pipe to produce the same pressure drop as a valve or fitting. This additional pipe length should be added to the length of the line in order to determine the total pressure drop.

*From Crane Co.'s "Engineering Data on Flow of Fluids in Pipes"—Technical Bulletin No. 405—1935. Parts dealing with steam pressure losses have been omitted.—Ed.

The equivalent length of pipe has been based upon the pressure drop values for the flow of water in pipes and upon the following coefficients of

$$H_1 = k\frac{V^2}{2g}$$

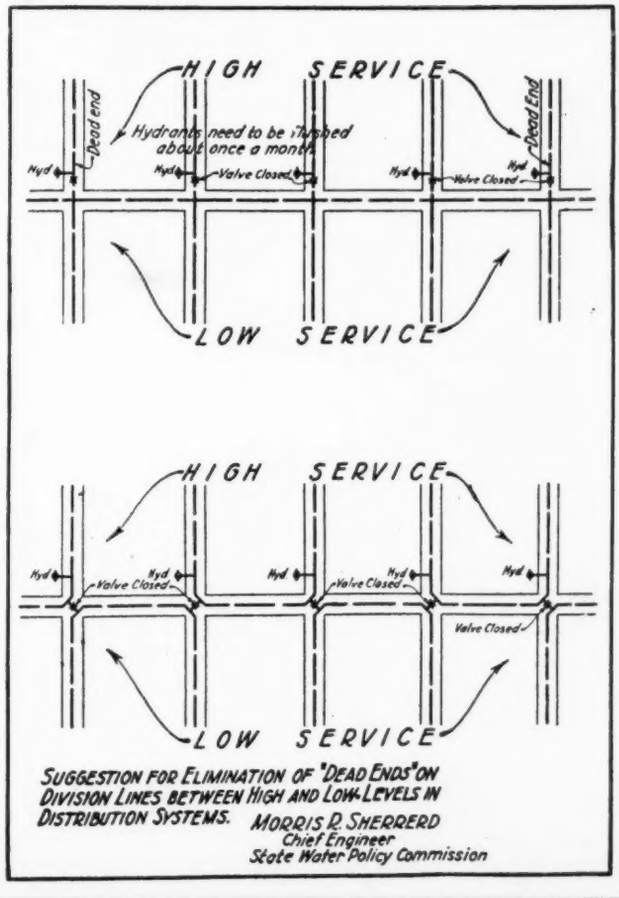
H_1 = Loss of head in ft.
k = Coefficient
V = Vel. in ft. per sec.
$2g = 64.4$

Type	*Coefficient*	*Authority*
Globe valves	10	Crane Tests
Angle Valve	5	Crane Tests
Return Bend	2.2	
Tee	1.8	Giesecke & Bladgett—Texas College
Short Radius Elbow	.9	Giesecke & Bladgett—Texas College
Med. Radius Elbow	.75	& Crane tests
Long Radius Elbow	.60	Bulletin No. 2712—U. of Texas.
Gate Valve (Open)	.19	Bulletin No. 252—U. of Wis. (Av.)
¼ Closed	1.15	Bulletin No. 252—U. of Wis. (Av.)
½ Closed	5.6	Bulletin No. 252—U. of Wis. (Av.)
¾ Closed	24.0	Bulletin No. 252—U. of Wis. (Av.)
Borda Entrance	.83	"Hydraulic" Daugherty (Average)
Sudden Enlargement		
d/D — ¼	.92	"Hydraulics" Daugherty
d/D — ½	.56	"Hydraulics" Daugherty
d/D — ¾	.19	"Hydraulics" Daugherty
Ordinary Entrance	.5	"Hydraulics" Daugherty
Sudden Contraction		
4/D = ¼	.42	"Hydraulics" Daugherty
d/D = ½	.33	"Hydraulics" Daugherty
d/D = ¾	.19	"Hydraulics" Daugherty
45° Elbow	.42	Bulletin No. 2712U. of Texas

ONE METHOD OF ELIMINATING DEAD ENDS

A means of eliminating dead ends of water mains where there are two types of water service, has been developed by Morris R. Sherrerd, Chief Engineer, New Jersey State Water Policy Commission.

The lower part of the illustration shows how by having a short gated connection between the two services, and by running the main around the block or square without using a cross fitting, dead ends are eliminated.



SUGGESTION FOR ELIMINATION OF "DEAD ENDS" ON DIVISION LINES BETWEEN HIGH AND LOW-LEVELS IN DISTRIBUTION SYSTEMS. MORRIS R. SHERRERD Chief Engineer State Water Policy Commission

PUMPS

DEFINITIONS AND VALUES

(Adopted by the Hydraulic Society)

Efficiency, Hydraulic (Symbol e_h).—The ratio of the useful power delivered in the water at the point of discharge where measured to the power delivered to the water by the impeller at the point of exit from the impeller.

Efficiency, Mechanical (Symbol e_m).—The ratio of the water horsepower to the horsepower required to drive the pump.

Efficiency, Overall (Symbol e).—Comprises all the losses in the pump and the driver, and indicates the economy of the entire unit.

Head, Total Dynamic (Symbol T.D.H.).—Total dynamic head is the vertical distance between the source of supply and point of discharge when pumping required capacity, plus friction entrance and exit losses.

Total dynamic head, as determined on test, where suction lift exists, is the reading of a mercury column connected to the suction nozzle of pump, plus the reading of a pressure gauge connected to discharge nozzle of pump, plus vertical distance betwen point of attachment of mercury column and center of gauge, plus excess, if any, of velocity head of discharge over velocity head of suction as measured at points where the instruments are attached, plus head of water resting on mercury column, if any.

Total dynamic head, as determined on test, where suction head exists, is the reading of a gauge attached to the discharge nozzle of pump, minus the reading gauge connected to the suction nozzle of pump, plus or minus vertical distance between centers of gauges (depending on whether suction gauge is below or above discharge gauge) plus excess, if any, of velocity head of discharge over velocity head of suction as measured at points where instruments are attached.

Total Dynamic Discharge Head is the total dynamic head minus dynamic suction lift, or plus dynamic suction head.

Head, Static (Symbol H_s).—Static head is the vertical distance between the free level of the source of supply and to the point of free discharge, or to the level of the free surface of the discharge water.

Head, Velocity (Symbol H_v).—The velocity head (sometimes called "Head due to Velocity") of water moving with a given velocity is the equivalent head through which it would have to fall to acquire the same velocity; or, in other words, the head necessary merely to accelerate the water. Knowing the velocity, we can readily figure the velocity head from the simple formula:

$$h = \frac{V^2}{2g}$$

in which "g" is acceleration due to gravity, or 32.16 feet per second; or, knowing the head, we can transpose the formula to $V = \sqrt{2gh}$, and thus obtain the velocity.

The velocity head is a factor both in figuring the total head from construction data and testing.

When estimating the total dynamic head of an installation, the head equivalent to the velocity of the water leaving the end of the discharge pipe line must be added to the static and friction head.

When testing a pump, certain velocity head corrections must be made, depending on the average velocity at the point where pressure readings are taken. The customary method of testing is to use a mercury column for obtaining the suction lift and a gauge to indicate the discharge or suction head, with gauge connections at or close to the pump openings.

The mercury column at the suction will show the dynamic suction head at the point of gauge connection. Included in this dynamic suction head is the velocity head as represented by the average velocity at that point.

The discharge gauge will show the dynamic pressure head at the point of gauge connection.

The sum of the two gauge readings, corrected to the same elevation, will give the total dynamic head produced by the pump, provided water flows at the same average velocity at the point of attachment of suction gauge as of discharge gauge. This condition will exist when suction and discharge openings are of equal size.

If the discharge pipe is of smaller diameter than the suction pipe, which is often the case, then it will be necessary to add to the total head, as shown by the gauges, the difference in velocity head between that of the discharge and that of the suction pipe at the point where gauges are connected.

If the discharge pipe is larger than the suction pipe, the difference in velocity head must be subtracted from the total head.

Velocity ft. per second	1	2	3	4	5	6	7
Velocity head in ft.	.02	.06	.14	.25	.39	.56	.76
Velocity ft. per second	8	8.5	9	9.5	10	10.5	
Velocity head in ft.	1.0	1.12	1.25	1.4	1.55	1.7	
Velocity ft. per second	11	11.5	12	13	14	15	
Velocity head in ft.	1.87	2.05	2.24	2.62	3.05	3.5	

Horsepower, Brake (Symbol b-hp.).—The actual horsepower required at the pump shaft to drive the pump $= \frac{\text{w-hp}}{e_m}$.

Brake horsepower is not applicable to direct-acting steam pumps.

Horsepower, Indicated (Symbol i-hp.).—The horsepower developed in the steam or liquid end calculated from indicator cards.

Suction Head (sometimes called head on suction) exists when the pressure measured at the suction nozzle and corrected to the center line of the pump is above atmospheric pressure.

Suction Head Dynamic, where static suction head exists, is the vertical distance from the source of supply, when pumping at required capacity, to center of pump, minus velocity head. minus entrance, friction and velocity losses; but not minus internal pump losses.

Suction head dynamic, as determined on test, is the reading of a gauge connected to suction nozzle of pump, minus vertical distance from center of gauge to center line of pump. Suction head, after deducting the various losses, may be a negative quantity, in which case a condition equivalent to suction will prevail.

Suction Head Static exists when the source of supply is above the center of pump and is the vertical distance from the free level of the source of supply to center of pump.

Suction Lift.—Suction lift exists when the suction measured at the pump nozzle and corrected to the center line of the pump is below atmospheric pressure.

Suction Lift Dynamic, where static suction lift exists, is the vertical distance from the source of supply, when pumping required capacity, to center of pump, plus velocity head, plus entrance, friction and velocity losses, but not including internal pump losses; where static suction head exists but where the losses exceed the static suction head the dynamic suction lift is the sum of the velocity head, entrance, friction and velocity losses, *minus* the static suction head, but not including internal pump losses.

Suction lift dynamic, as determined on test, is the reading of a mercury column connected to suction nozzle of pump, plus vertical distance between point of attachment of mercury column to center of pump, plus head of water resting on mercury column, if any.

Suction Lift Static exists when the source of supply is below the center of pump and is the vertical distance from the free level of source of supply to center of pump.

Viscosity is that property of a liquid which resists any force tending to produce flow. Viscosity is a property independent of specific gravity.

SOME NOTES ON ELECTRICALLY DRIVEN CENTRIFUGAL PUMPS

By HOMER E. BECKWITH*

In the past few years there has been a rapid change from steam to electrically driven centrifugal pumps, especially in the smaller water works plants. The many advantages of electric power are coming to be more and more realized, but unfortunately in many cases a full knowledge of the nature of centrifugal pumps does not seem to have accompanied their adoption. It is economy of the highest order, therefore, to secure the advice of a competent engineer before purchasing any centrifugal pumping equipment.

Centrifugal pumps are designed to operate under fixed conditions, and any appreciable change from design conditions will result in decreased efficiency.

Installations have been found where pumps were working against more than the design head, or against less than the design head, or with the discharge or suction partly closed to control the rate of discharge. Or pumps have been installed without knowledge that the friction head is a part of the total head against which the pump operates. All of these factors adversely affect the performance of the equipment to such an extent that the cost of efficient machinery is often wasted every few months through inefficient operation. Also, accidents can occur to equipment in operation which decreases its efficiency.

For some time the writer has felt that some simple method should be available to the average water works operator whereby he could check up on his pumps. Table 1 was worked up for personal use, but may prove to be of interest. A slide rule was used in its preparation, but it should be accurate to a fraction of 1 per cent. With this table, it is believed that the work of securing overall wire to water efficiencies will be reduced to a minimum. Table 1 shows the number of gallons pumped per kilowatt hour against a given head, assuming the motor and pumps have efficiencies of 100 per cent. A rough check can be made by dividing a month's pumpage in gallons by the kilowatt hours consumed. This gives the number of gallons pumped per kilowatt hour. With the pump running, determine the average total head in feet (including suction) against which the pump works. From the table secure the number of gallons which would have been pumped at the head if the installation were 100 per cent efficient. Divide the number of gallons actually pumped per kilowatt hour by the theoretical value given in the table. This gives the overall wire to water efficiency of the installation. To illustrate:

Assume a monthly pumpage of 18,620,000 gals., a total head of 200 ft., and a power consumption of 20,000 kilowatt hours. Dividing 18,620,000 by 20,000 we get 931 gals. per kilowatt hour. For 100 per cent efficiency the tables indicate that the discharge would be 1,592 gals. against a head of 200 ft. Dividing the actual discharge per kilowatt hour by the theoretical value we have: $\frac{931}{1{,}592} = 58.5$ per cent overall efficiency.

A more accurate method of making the tests is to measure the power input for an hour, or other convenient period of time. During this period measure the output of the pump with a pitometer, or any other suitable main line meter. Keep a close record also of the discharge pressure and of the suction. The integrations on most electric meters in pumping stations cannot be read closely enough for short tests. However, the power company will furnish the number of watts consumed for each revolution of the disk, and by counting its revolutions for 10 or 20 minutes the rate of power input can be closely ascertained. Or the power company might measure the power by means of special equipment. Where more than one pump is taking power through the master meter at the same time, this latter method is the only feasible one.

To enter the tables, the total head in feet must be secured. If the pressure gauge reads in pounds, transfer the pressure to feet by multiplying the pounds of pressure by 2.31. The suction will probably be expressed in inches of mercury. Change this to feet of water by multiplying by 1.13. Also measure the vertical distance between the center of the pressure gauge and the point of suction measurement. The total head then becomes the addition of:

Discharge pressure, in feet .....
Suction, in feet .....
Vertical distance pressure gauge (Is above point of suction measurement), feet .....

Velocity head has been ignored, as it is a small factor for the relatively high heads which usually exist in water works operation.

If water is delivered to the pump under pressure, then the pump works against a head equal to the difference between the discharge pressure and the inlet pressure.

From the data secured during the test, determine the gallons delivered per kilowatt hour. As before, divide this by the theoretical value secured from the table for the head against which the pump worked. This gives the overall wire to water efficiency of the installation.

As an example, let us assume an installation where we secured the following test data:

K.W. input to motor 90.0
Rate of discharge..... 51,480 gal. per hour
Number of gallons delivered per k.w.h..... 572

Table I—Gallons of Water Delivered per Kilowatt Hour Against Various Heads on Theoretical Assumption That Pump and Motor Are 100 Per Cent Efficient

H = head in feet. G = gallons per kilowatt hour

H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G
1	318,200	51	6,240	101	3,151	151	2,108	201	1,583	251	1,268	301	1,058	351	907	401	794	451	706
2	159,100	52	6,120	102	3,120	152	2,094	202	1,575	252	1,263	302	1,054	352	904	402	792	452	704
3	106,100	53	6,005	103	3,090	153	2,080	203	1,567	253	1,258	303	1,051	353	902	403	790	453	703
4	79,560	54	5,894	104	3,060	154	2,067	204	1,560	254	1,253	304	1,047	354	899	404	788	454	701
5	63,650	55	5,786	105	3,031	155	2,053	205	1,552	255	1,248	305	1,044	355	897	405	786	455	700
6	53,040	56	5,683	106	3,002	156	2,040	206	1,545	256	1,243	306	1,040	356	894	406	784	456	698
7	45,460	57	5,583	107	2,974	157	2,027	207	1,537	257	1,239	307	1,037	357	892	407	782	457	697
8	39,780	58	5,487	108	2,947	158	2,014	208	1,530	258	1,234	308	1,033	358	889	408	780	458	695
9	35,360	59	5,394	109	2,920	159	2,002	209	1,523	259	1,229	309	1,030	359	887	409	778	459	694
10	31,830	60	5,304	110	2,893	160	1,989	210	1,516	260	1,224	310	1,027	360	884	410	776	460	692
11	28,930	61	5,217	111	2,867	161	1,977	211	1,508	261	1,220	311	1,024	361	882	411	775	461	691
12	26,520	62	5,133	112	2,842	162	1,965	212	1,501	262	1,215	312	1,020	362	879	412	773	462	689
13	24,480	63	5,051	113	2,816	163	1,952	213	1,494	263	1,211	313	1,017	363	877	413	771	463	687
14	22,730	64	4,972	114	2,794	164	1,940	214	1,487	264	1,206	314	1,014	364	875	414	769	464	686
15	21,220	65	4,896	115	2,766	165	1,929	215	1,480	265	1,202	315	1,011	365	873	415	767	465	685
16	19,890	66	4,822	116	2,744	166	1,917	216	1,474	266	1,197	316	1,007	366	870	416	765	466	683
17	18,720	67	4,750	117	2,720	167	1,906	217	1,467	267	1,193	317	1,004	367	868	417	763	467	682
18	17,680	68	4,680	118	2,697	168	1,894	218	1,460	268	1,188	318	1,001	368	865	418	761	468	680
19	16,750	69	4,611	119	2,674	169	1,883	219	1,453	269	1,184	319	998	369	863	419	760	469	679
20	15,910	70	4,547	120	2,652	170	1,872	220	1,447	270	1,179	320	995	370	860	420	758	470	677
21	15,150	71	4,482	121	2,630	171	1,861	221	1,440	271	1,175	321	992	371	858	421	756	471	676
22	14,470	72	4,420	122	2,609	172	1,851	222	1,434	272	1,170	322	989	372	856	422	754	472	675
23	13,830	73	4,360	123	2,588	173	1,840	223	1,427	273	1,168	323	986	373	854	423	753	473	674
24	13,260	74	4,301	124	2,567	174	1,829	224	1,421	274	1,162	324	982	374	851	424	751	474	672
25	12,730	75	4,243	125	2,546	175	1,819	225	1,414	275	1,158	325	979	375	849	425	749	475	671
26	12,240	76	4,188	126	2,526	176	1,809	226	1,408	276	1,154	326	976	376	847	426	747	476	669
27	11,790	77	4,133	127	2,506	177	1,798	227	1,402	277	1,150	327	973	377	845	427	746	477	668
28	11,370	78	4,080	128	2,486	178	1,788	228	1,396	278	1,146	328	970	378	842	428	744	478	666
29	10,970	79	4,028	129	2,467	179	1,778	229	1,390	279	1,142	329	968	379	840	429	742	479	665
30	10,610	80	3,978	130	2,448	180	1,768	230	1,384	280	1,137	330	965	380	838	430	740	480	663
31	10,270	81	3,929	131	2,429	181	1,758	231	1,378	281	1,133	331	962	381	836	431	739	481	662
32	9,945	82	3,882	132	2,411	182	1,749	232	1,372	282	1,129	332	959	382	833	432	737	482	660
33	9,644	83	3,834	133	2,393	183	1,739	233	1,366	283	1,125	333	956	383	831	433	736	483	659
34	9,360	84	3,789	134	2,375	184	1,729	234	1,360	284	1,121	334	953	384	829	434	734	484	658
35	9,093	85	3,744	135	2,358	185	1,720	235	1,354	285	1,117	335	950	385	827	435	732	485	657
36	8,840	86	3,701	136	2,340	186	1,711	236	1,349	286	1,113	336	947	386	825	436	730	486	655
37	8,601	87	3,658	137	2,323	187	1,702	237	1,343	287	1,109	337	945	387	823	437	729	487	654
38	8,375	88	3,617	138	2,306	188	1,693	238	1,337	288	1,105	338	942	388	820	438	727	488	652
39	8,160	89	3,576	139	2,292	189	1,684	239	1,332	289	1,102	339	939	389	818	439	725	489	651
40	7,956	90	3,536	140	2,274	190	1,675	240	1,326	290	1,098	340	936	390	816	440	723	490	650
41	7,762	91	3,497	141	2,257	191	1,666	241	1,320	291	1,094	341	934	391	814	441	722	491	649
42	7,577	92	3,458	142	2,241	192	1,658	242	1,315	292	1,090	342	931	392	812	442	720	492	647
43	7,401	93	3,422	143	2,225	193	1,649	243	1,310	293	1,087	343	929	393	810	443	719	493	646
44	7,233	94	3,386	143	2,210	194	1,640	244	1,304	294	1,083	344	926	394	807	444	717	494	644
45	7,072	95	3,350	145	2,195	195	1,632	245	1,299	295	1,079	345	923	395	805	445	716	495	643
46	6,916	96	3,315	146	2,180	196	1,624	246	1,294	296	1,075	346	920	396	804	446	714	496	642
47	6,771	97	3,281	147	2,165	197	1,615	247	1,288	297	1,072	347	918	397	802	447	712	497	641
48	6,630	98	3,248	148	2,150	198	1,608	248	1,284	298	1,068	348	915	398	800	448	710	498	639
49	6,495	99	3,215	149	2,136	199	1,600	249	1,278	299	1,065	349	913	399	798	449	709	499	638
50	6,365	100	3,183	150	2,122	200	1,592	250	1,273	300	1,061	350	910	400	796	450	707	500	636

*The Pitometer Co., New York City.
[1]From WATER WORKS AND SEWERAGE.

Pressure	146 lb. or 337 ft.
Suction	15 in. or 17 ft.
Difference in gauge elevation	1 ft. 1 ft.
Total head	355 ft.
Theoretical discharge 355 ft. head (tables)	897 gal.
Overall efficiency	$\frac{572}{897}$ = 64 per cent

Provided a suction gauge is not available an approximation may be secured by measuring the vertical distance from the level of water in the clear well to the center of the pressure gauge, adding to this measured distance about one foot for loss in bends, etc.

Results of Checking Efficiency

The solution of each instance of inefficient operation is a problem in itself. No hard and fast rule for procedure can be given. In the case cited of obsolete design, the economical procedure was to replace the pump with one of modern design, keeping the old unit as a standby. In other instances, a change in the impeller will often return the pump to high efficiency. In one case, where a multiple stage pump was working against a high head, it was found that its inefficiency was caused by a defective gasket between the upper and lower parts of the pump case. This permitted the water to flow back from the higher to the lower stages, thereby decreasing both the rate of discharge and the efficiency. A new gasket was all that was necessary to solve the difficulty. In another instance, it was found that some of the ports had become plugged with wood, probably when a filter bed had broken three years previously. At least once, an impeller was found loose on the shaft.

About two years ago, an instance was uncovered where an apparent inefficiency was due to the power meter being set high. As soon as the test figures were in, the striking thing was not so much the low efficiency indicated, as the fact that the motor was apparently taking power at a rate which would have caused it to "burn up" from over-loading.

This list could be prolonged almost indefinitely, but it is believed that enough illustrations have been given to show the value of continuous checks. Many progressive operators show on their monthly or weekly reports the number of gallons pumped for the period for each kilowatt hour of power consumed. This is a splendid practice. Whenever our company, in making these tests, has found a low efficiency indicated, our experience has shown that the power companies and the pump manufacturers are most willing to cooperate in restoring the plant to efficient operation.

Assuming that the motor is about 90 per cent efficient, the following overall wire to water efficiencies may be expected from centrifugal pumps of good design:

g. p. m.	Per cent
200	49
400	54
600	58
800	60
1000	63
1500	67

More expensive pumps of best design will often show values of three to five per cent higher than the above figures.

In order to illustrate how the table can be used to compute probable savings to result from the substitution of a more efficient unit for an existing inefficient one, let us assume that 1,000 g.p.m. are being pumped against a total head of 200 ft., and a discharge of only 796 gal. per k.w.h. is secured. This gives us $\frac{796}{1592}$ = 50 per cent efficiency. Should this installation be replaced by one capable of an overall efficiency of 65 per cent, we would get 1,592 × 65 per cent = 1,035 gal. per k.w.h.

With an assumed monthly pumpage of 30,000,000 gal., it would require, with the original installation, $\frac{30{,}000{,}000}{796}$ = 37,676 k.w.h. to pump the water.

With the proposed more efficient installation it would require $\frac{30{,}000{,}000}{1{,}035}$ = 28,986 k.w.h.

This is a saving of 8,690 k.w.h., or 23 per cent, in the actual power consumption. There is also a similar decrease in the demand rate. The pumping rate of 1,000 g.p.m. equals 60,000 g.p.m.

$$\frac{60{,}000}{796} = 75 \text{ k.w. demand rate}$$

and

$$\frac{60{,}000}{1{,}035} = 58 \text{ k.w. demand rate.}$$

This is a decrease of 17 k.w. or 23 per cent in the demand rate. Both the demand rate and the actual consumption of power are therefore decreased in the same proportion. If the power cost averages 2 ct. per k.w.h., the reduction amounts to 8,690 × 0.02 = $173.80 per month, or $2,085.60 per year.

A word of warning may not be amiss here. While the large pumps are more efficient than the smaller ones, pumps larger than actually required should not usually be used. Often the additional friction loss due to higher velocity will offset the increased efficiency, and the higher demand charges will boost the total bill considerably.

Assume an installation which consumes 12,000 k.w.h. per month and which has a demand schedule as follows:

5,000 k.w.h. @ 0.030c	$150.00
5,000 k.w.h. @ 0.026c	130.00
2,000 k.w.h. @ 0.012c	24.00
Total	$304.00

If we use a smaller installation with half this demand rate we might use 13,000 k.w.h. per month to pump the same amount of water, but the total bill would be less:

2,500 k.w.h. @ 0.030c	$ 75.00
2,500 k.w.h. @ 0.026c	65.00
8,000 k.w.h. @ 0.012c	96.00
Total	$236.00

This is a saving of $68.00 per month although more power is actually consumed. And, after all, the object in securing increased efficiency is to pump more water per dollar.

Measuring Output of Water

Table I previously given has another use. Many plants, especially smaller ones, have no master meters. With the old displacement type pump it was possible to secure the approximate amount of water pumped by installing a pump stroke counter and multiplying the number of strokes by the discharge in gallons per stroke. If the pump were permitted to get into a state of disrepair, this measurement was apt to be in error, but if the pump were kept in good condition it was reasonably accurate. The method about to be outlined for obtaining the output of water from electrically operated centrifugal pumps has possibly a degree of accuracy comparable to the pump counter method.

From the efficiency curve furnished with the pump, determine the pump efficiency for the head under which the pump operates. The curve will show the pump efficiency only. The combined pump and motor efficiency, the so-called wire to water efficiency, will be about 90 per cent of the efficiency shown for the pump alone. From Table 1 secure the theoretical gallons per kilowatt hour for the head under which the pump is operated. Multiply this by the overall wire to water efficiency just secured. This gives the number of gallons per kilowatt hour the pump should deliver. Multiply this by the total number of kilowatt hours used over any given period of time and the result should be the number of gallons pumped over the same period. If a curve for the pump is not available and if the manufacturer cannot supply one, approximate results can be obtained by using the efficiencies previously given in this paper. To illustrate:

Assume a pump with an efficiency of 65 per cent operating at a total head of 200 ft. Then 90 per cent of 65 would give an overall wire to water efficiency of 58.5 per cent. If the installation were 100 per cent efficient, Table 1 indicates the discharge would be 1,592 gallons per kilowatt hour. With an overall efficiency of 58.5 per cent the discharge would be 1,592 × 58.5 per cent, or 931 gal. If the power consumption for the month be 20,000 kilowatt hours, then the total pumpage becomes 20,000 × 931 or 18,620,000 gal. for the month.

While this method of computing pumpage will not, as a rule, give results as satisfactory as those secured from a master meter, it does give a close approximation in instances where a master meter is not available. As a matter of fact, in one instance where this method was used to check the master meter, it was found that it would have been impossible for the pump to have delivered the water shown on the master meter unless the installation had an efficiency of about 125 per cent. This, of course, would be impossible. Whenever a pump installation gives an efficiency over 100 per cent, the secret of perpetual motion will have been discovered. In the case just cited, the master meter was about 100 per cent fast.

In outlining the tests in this paper it has not been intended to supplant the more detailed methods used by professional engineers, but to make available to the average water works operator a method of checking which will give reasonably accurate results.

COMPUTING HORSEPOWER FROM REVOLVING WATT-HOUR METERS

A simple method of accurately measuring power consumption is of general interest to the owner or operator of any electrically driven pump. A periodical record of the power consumption, capacity of the pump, and the measurement of the pumping level assists in maintaining operation at maximum efficiency and gives an indication as to the proper time for reconditioning or modernizing the installation.

The power consumption is measured by the Watt-Hour Meter, usually located on the switchboard in the pump house adjacent to the motor. Large units require current and/or potential transformers, so that the watt-hour meter reading must be multiplied by the ratio of these transformers to obtain the correct measurement of power consumption of the motor.

A motor which draws 200 amp. at 440 volts may be metered through current transformers rate 200 amp. primary and 5 amp. secondary, so that 5 amp. would pass through the watt-hour meter. No potential transformers being used, the watt-hour meter reading, multiplied by the ratio of 200 to 5, would give the amount of power in the main circuit.

Asssuming that a motor draws 600 amp. at 2300 volts, potential as well as current transformers are required. If the ratio is 60 to 5 amp. on the current, and 2300 to 115 on the potential transformers, the watt-hour meter reading multiplied by the ratio of 60 to 5 and in addition, by the ratio of 2300 to 115, will give a true measure of the power consumption in the main circuit. The correct ratio is usually stamped on a brass nameplate attached to the transformer.

Disk constants and multipliers for practically all modern watt-hour meters now in use for single and three phase, 110-220-440 volts are shown in the chart below.

Use of Chart

First determine the make, type, volts and amp. of the meter. If no current or potential transformers are used, refer to the chart and determine M value for the meter. The M × r.p.m. of disk = hp. input to motor for example, a meter, G.E., type D-3, 220 volt, 15 amp., K = 4.0, M = .3217, number of revolutions of disk in one minute = 20. Then .3217 × 20 = 6.434 h.p. input to motor.

As another example consider an installation where current transformers having a ratio of 20 to 1 are used. Meter, Westinghouse type OA, 220 volt, 5 amp., K = 1⅓, M = .1027, number of revolutions of disk in one minute = 21. Then, .1072 × 21 × 20 = 45.02 h.p. input to motor.

Disk constants K are included in the accompanying chart because occasionally the manufacturer's nameplate has been removed, in which event the constant K is marked on the meter. To determine the M value in such cases, find a K in the table corresponding to that on the meter in question. The M applying will be the one adjacent to and on the right of this K.

Definitions:

K—A constant which represents the number of watt-hours passed through the meter while the disk makes one revolution.

M—A factor which, when multiplied by the number of revolutions of the disk, in one minute, gives h.p. input to motor.

Mathematically, $M = \frac{K \times 60}{746}$

The h.p. values expressed above relate to input to motor. The rating of motors is in terms of h.p. output. Therefore, the h.p. output or brake h.p. is determined by multiplying the h.p. input by the motor efficiency, which can be obtained from the motor manufacturer.

Chart of Constants and Multipliers

For Use in Determining KW Input, HP Input or BHP from Revolutions of Watthour Meter Disks

110 Volt—Single Phase

Amp.	General Electric 1		General Electric 1-10		General Electric 1-14		General Electric 1-16		Sangamo H		Westinghouse B, C, OA, OB	
	K	M	K	M	K	M	K	M	K	M	K	M
5	.3	.0241	.25	.0201	.3	.0241	.6	.0483	5/24	.0168	⅓	.0268
10	.6	.0483	.5	.0402	.6	.0483	1.2	.0965	5/12	.0335	⅔	.0536
15	1.0	.0804	.75	.0603	.9	.0724	1.8	.1448	5/8	.0503	1	.0804
25	1.5	.1206	1.25	.1005	1.5	.1206	3.0	.2413	2 5/24	.0838	1⅔	.1340
50	3.0	.2413	2.5	.2011	3.0	.2413	6.0	.4826	2 1/12	.1676	3⅓	.2681

220 Volt—Single Phase

Amp.	General Electric 1		General Electric 1-10		General Electric 1-14		General Electric 1-16		Sangamo H		Westinghouse B, C, OA, OB	
	K	M	K	M	K	M	K	M	K	M	K	M
5	.6	.0483	.5	.0402	.6	.0483	1.2	.0965	5/12	.0335	⅔	.0536
10	1.25	.1005	1.0	.0804	1.2	.0965	2.4	.1930	5/6	.0670	1⅓	.1072
15	2.0	.1609	1.5	.1206	1.8	.1448	3.6	.2895	1 1/4	.1005	2	.1609
25	3.0	.2413	2.5	.2011	3.0	.2413	6.0	.4826	2 1/12	.1676	3⅓	.2681
50	6.0	.4826	5.0	.4021	6.0	.4826	12.0	.9651	4 1/6	.3351	6⅔	.5362

110 Volt—Three Phase

Amp.	General Electric D-3		General Electric D-6 & D-7		General Electric D-14		Sangamo H		Westinghouse C, OA, OB, RO.	
	K	M	K	M	K	M	K	M	K	M
5	.6	.0483	.6	.0483	1.2	.0965	5/12	.0335	2/3	.0536
10	1.25	.1005	1.2	.0965	2.4	.1930	5/6	.0670	1 1/3	.1072
15	2.0	.1609	1.8	.1448	3.6	.2895	1 1/4	.1005	2	.1609
25	3.0	.2413	3.0	.2413	6.0	.4826	2 1/12	.1676	3 1/3	.2681
50	6.0	.4826	6.0	.4826	12.0	.9651	4 1/6	.3351	6 2/3	.5362

220 Volt—Three Phase

Amp.	General Electric D-3		General Electric D-6 & D-7		General Electric D-14		Sangamo H		Westinghouse C, OA, OB, RO.	
	K	M	K	M	K	M	K	M	K	M
5	1.25	.1005	1.2	.0965	2.4	.1930	5/6	.0670	1 1/3	.1072
10	2.5	.2011	2.4	.1930	4.8	.3861	1 2/3	.1340	2 2/3	.2145
15	4.0	.3217	3.6	.2895	7.2	.5791	2 1/2	.2011	4	.3217
25	6.0	.4826	6.0	.4826	12.0	.9651	4 1/6	.3351	6 2/3	.5362
50	12.5	1.005	12.0	.9651	24.0	1.930	8 1/3	.6702	13 1/3	1.072

440 Volt—Three Phase

Amp.	General Electric D-3		General Electric D-6 & D-7		General Electric D-14		Sangamo H		Westinghouse C, OA, OB, RO.	
	K	M	K	M	K	M	K	M	K	M
5	2.5	.2011	2.4	.1930	4.8	.3861	1 2/3	.1340	2 2/3	.2145
10	5.0	.4021	4.8	.3861	9.6	.7721	3 1/3	.2681	5 1/3	.4289
15	7.5	.6032	7.2	.5791	14.4	1.158	5	.4021	8	.6434
25	12.5	1.005	12.0	.9651	24.0	1.930	8 1/3	.6702	13 1/3	1.072
50	25.0	2.011	24.0	1.930	48.0	3.861	16 2/3	1.340	26 2/3	2.145

hp. Input = "M" × Revolutions per minute of Disk

hp. Input = "K" × Number of Revolutions × 3600.

Sec. × 746

Important—Where instrument transformers are used, be sure that figure computed from revolutions of disk and table be multiplied by ratio of instrument transformers.

(From Byron-Jackson Bulletin, "Deep-Well Turbine Pumps.")

Terminology in Pumping*

Static Head

Static Head is the vertical distance in feet beeween the free level of the source of supply and the point of free discharge, or to the level of the free surface of the discharge water.

Total Dynamic Head

Total Dynamic Head, as determined on test, where Suction Lift exists, is the reading of a mercury column connected to the suction nozzle of pump, plus the reading of a pressure gauge connected to discharge nozzle of pump, plus vertical distance between point of attachment of mercury column and center of gauge, plus excess, if any, of Velocity Head of discharge over Velocity Head of suction as measured at points where the instruments are attached, plus head of water resting on mercury column, if any.

Total Dynamic Head, as determined on test, where Suction Head exists, is the reading of a gauge attached to the discharge nozzle of pump, minus the reading of gauge connected to the suction nozzle of pump, plus or minus vertical distance between centers of gauges (depending on whether suction gauge is below or above discharge gauge), plus excess, if any, of Velocity Head of discharge over Velocity Head of suction as measured at points where instruments are attached.

Total Dynamic Discharge Head, is the Total Dynamic Head minus Dynamic Suction Lift, or plus Dynamic Suction Head.

Total Dynamic Head is the vertical distance between source of supply and point of discharge when pumping the required capacity, plus Velocity Head, plus friction and entrance losses.

*From "Hydraulic Data," an Ingersoll-Rand Hand-Book.

Suction Lift

Suction Lift exists where the source of supply is below the center of pump.

Static Suction Lift is the vertical distance from the free level of source of supply to center of pump.

Dynamic Suction Lift is the vertical distance from the source of supply, when pumping required capacity, to center of pump, plus Velocity Head, plus entrance, and friction losses; but not including internal pump losses.

Dynamic Suction Lift, as determined on test, is the reading of a mercury column connected to suction nozzle of pump, plus vertical distance between point of attachment of mercury column to center of pump, plus head of water resting on mercury column, if any.

Suction Head

Suction Head (sometimes called Head on Suction), exists when source of supply is above center of pump.

Static Suction Head is the vertical distance from the free level of the source of supply to center of pump.

Dynamic Suction Head is the vertical distance from the source of supply, when pumping at required capacity, to center of pump, minus Velocity Head, minus entrance, and friction losses; but not minus internal pump losses.

Dynamic Suction Head, as determined on test, is the reading of a gauge connected to suction nozzle of pump, minus vertical distance from center of gauge to center of line pump. Suction Head, after deducting the various losses, may be a negative quantity, in which case a condition equivalent to Suction Lift will prevail.

S. R. DRESSER MANUFACTURING COMPANY

BRADFORD, PENNSYLVANIA

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Manufacturers of

PRODUCTS TO HELP YOU WITH YOUR PIPE-JOINT PROBLEMS

General—The pipe couplings and pipe-line repair products described below have been used for 47 years on many of the country's largest water and sewage lines. (*Example*: 40-mile, 60″ water line at Birmingham, Ala.)

Pipe-Joint Advisory Service—Recommendations without obligation will be furnished by Dresser Laboratories for the solution of unusual pipe-joint problems on receipt of necessary details, including: service (water, air, sludge, etc.), maximum working pressure, description of job, temperature range, etc., and the outside diameter, thickness, and kind of pipe, plus working sketches wherever possible.

DRESSER COUPLINGS, STYLE 38

Fig. 164d. Style 38 Steel Coupling (12″ I.D.). Joins plain-end steel (and cast-iron) pipe.

Purpose—The Dresser Coupling is a "factory-made" pipe joint, which (when simply *assembled* on plain-end pipe) makes a *flexible*, permanently tight connection.

Description — Each standard Style 38 Steel Coupling is made up of one middle ring, two followers, two *resilient*, rubber gaskets, and a number of bolts (see cross-section below).

Advantages of the Dresser Coupling Are—(1) *Permanent Tightness*—confirmed by *millions* of field installations. (2) *Flexibility*—for absorbing pipe movements, expansion, settling, curves, etc. (3) *Simplicity*—unskilled labor, using only a wrench, can quickly install — or disconnect. (4) *Strength*—ample to hold safely any specified working pressure. (5) *Economy*—the only joint that insures *true* economy throughout its life.

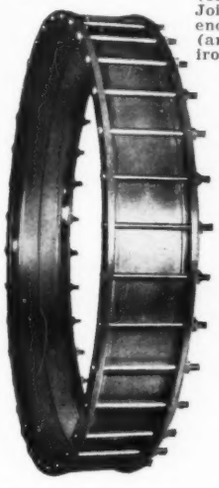


Fig. 166. Style 38 Steel Coupling (60″ I.D.) for joining plain-end, large-diameter pipe above 24″.

Sizes Available—Style 38 Couplings are made for all standard and special sizes, as well as all kinds of *plain-end* pipe. Size range: ⅜″ to largest pipe made.

How to Order—When ordering, or asking for quotations on Style 38 Couplings, state: (1) quantity; (2) style number; (3) nominal size and outside diameter of pipe; (4) kind of pipe (steel, cast-iron, etc.); (5) working pressure; and (6) service (water, air, sludge, etc.). (On *special* orders, give the foregoing, plus details listed above under "Pipe-Joint Advisory Service.")

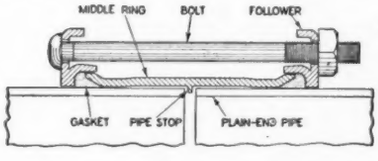


Fig. 165. Longitudinal section through a Style 38 Coupling (of typical size).

Fig. 168b. Style 38 Steel Coupling (5⅝″ Cas.) for joining plain-end, light-wall steel pipe.

Fig. 195b. Style 40 Long Sleeve (6″ I.D.). Is like Style 38 except has longer body to span variations in space between pipe ends.

DRESSER COUPLINGS, STYLE 53

Fig. 174b. Style 53 Cast Coupling (12″ C.I.P.). For use with plain-end, cast-iron pipe under corrosive conditions. Similar to Style 38, except of cast material. Sizes available: 2″ to 30″ incl. (An alternate for these and larger sizes is Style 38 Steel Coupling for cast-iron pipe.) Standard steel bolts, either galvanized or cadmium-plated, are regularly supplied with Style 53—though cast bolts can also be furnished.

DRESSER FITTINGS, STYLE 65

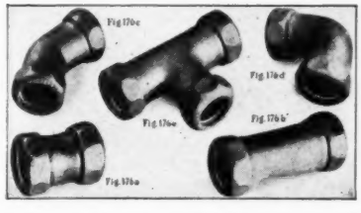
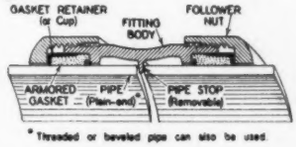


Fig. 176. Style 65 Fittings join plain-end, standard steel pipe. Shown are (all 1¼″ I.D.): Style 65 Coupling (Fig. 176a); Style 65A Long Coupling (Fig. 176b); Style 65, 45° Ell (Fig. 176c); Style 65, 90° Ell (Fig. 176d); and Style 65 Tee (Fig. 176e).

Working Principle of Style 65—Threaded follower nuts on each end of fitting, when tightened with an ordinary wrench, cause *resilient* gaskets to compress tightly around ends of the pipe, effectively sealing in the contents of the line under all conditions. Resulting joint is permanently tight, yet flexible enough to absorb and cushion safely all vibration, expansion, contraction, and deflection movements of the pipe.

Purpose—Style 65 Fittings are recommended for: (1) Water *self-contained*, *flexible* pipe joints lines. (2) Hot-water lines. (3) Air lines. (4) Sewage lines of all kinds.

No Pipe Threading—Style 65 Fittings come completely assembled and may be installed in a moment with only a wrench. Just loosen nuts, slip in plain-end pipe, tighten with wrench. Result—a permanently tight, *flexible* pipe joint that acts as a union and makes exact lengths of pipe unnecessary.



Dresser Repair Clamps and Repair Sleeves for repairing pipe and pipe-joints

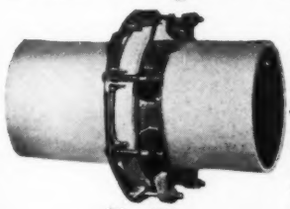


Fig. 238

Style 60 Bell-Joint Clamp (12″ C.I.P.). Repairs and prevents leaks in bell joints. Readily adjusted to variations in bell and spigot diameters.

Fig. 266

Style 57 Cast Split Sleeve (12″ C.I.P.). Encloses and permanently repairs splits and holes up to 8″ long in straight run of pipe.

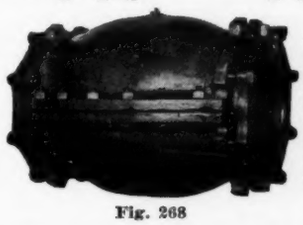
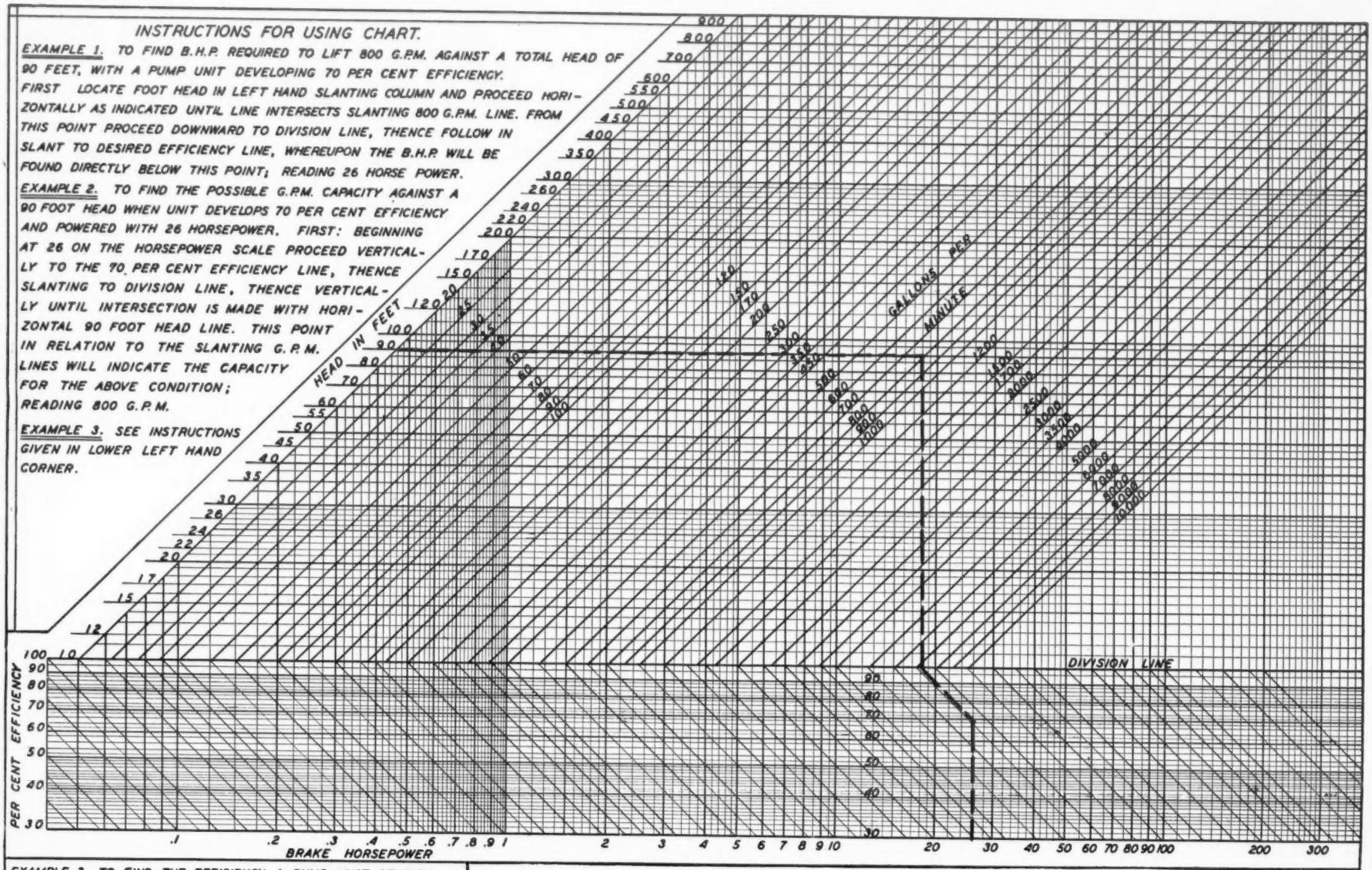


Fig. 268

Style 26 Cast Split Sleeve (12″ C.I.P.). Encloses and permanently repairs broken or split bell joints.

Write on your business letterhead for our Pipe-joint Handbook No. 36. Sent freely only on request.


INSTRUCTIONS FOR USING CHART.
EXAMPLE 1. TO FIND B.H.P. REQUIRED TO LIFT 800 G.P.M. AGAINST A TOTAL HEAD OF 90 FEET, WITH A PUMP UNIT DEVELOPING 70 PER CENT EFFICIENCY. FIRST LOCATE FOOT HEAD IN LEFT HAND SLANTING COLUMN AND PROCEED HORIZONTALLY AS INDICATED UNTIL LINE INTERSECTS SLANTING 800 G.P.M. LINE. FROM THIS POINT PROCEED DOWNWARD TO DIVISION LINE, THENCE FOLLOW IN SLANT TO DESIRED EFFICIENCY LINE, WHEREUPON THE B.H.P. WILL BE FOUND DIRECTLY BELOW THIS POINT; READING 26 HORSE POWER.
EXAMPLE 2. TO FIND THE POSSIBLE G.P.M. CAPACITY AGAINST A 90 FOOT HEAD WHEN UNIT DEVELOPS 70 PER CENT EFFICIENCY AND POWERED WITH 26 HORSEPOWER. FIRST: BEGINNING AT 26 ON THE HORSEPOWER SCALE PROCEED VERTICALLY TO THE 70 PER CENT EFFICIENCY LINE, THENCE SLANTING TO DIVISION LINE, THENCE VERTICALLY UNTIL INTERSECTION IS MADE WITH HORIZONTAL 90 FOOT HEAD LINE. THIS POINT IN RELATION TO THE SLANTING G.P.M. LINES WILL INDICATE THE CAPACITY FOR THE ABOVE CONDITION; READING 800 G.P.M.
EXAMPLE 3. SEE INSTRUCTIONS GIVEN IN LOWER LEFT HAND CORNER.
HEAD IN FEET
GALLONS PER MINUTE
DIVISION LINE
PER CENT EFFICIENCY
BRAKE HORSEPOWER

EXAMPLE 3. TO FIND THE EFFICIENCY A PUMP MUST DEVELOP IN ORDER TO DELIVER 800 G.P.M. AGAINST A 90 FOOT HEAD WITH 26 HORSEPOWER. PROCEED AS IN EXAMPLE 1 TO DIVISION LINE, THEN SLANTWISE UNTIL INTERSECTION IS MADE WITH THE VERTICAL 26 HORSEPOWER LINE. THIS POINT WILL LOCATE THE HORIZONTAL EFFICIENCY LINE; READING 70 PER CENT.

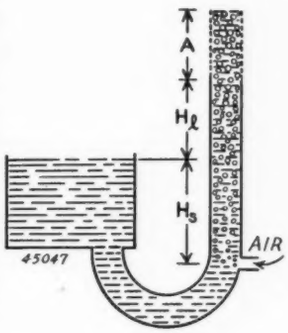
Chart for Determining Head, Capacity, Efficiency, Horse Power With Any Three Conditions Known

(This chart from Peerless Pump Bulletin of Ford Machinery Corp.)

PUMPING BY AIR LIFT*

Principle

The method of pumping with compressed air can be illustrated by the drawing at the right.



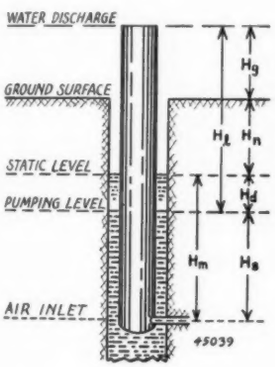
If the tank is filled with water, it is clear that it will rise in the vertical column to the same level as in the tank. Now assume that a specific quantity of compressed air is allowed to continuously flow into the pipe. The mixture of air and water in the vertical pipe, because it is lighter than the water in the tank, would rise a distance of $H_1 + A$ above the water in the tank. This is true because the light mixture of air and water in the column $H_s + H_1 + A$ just balances the head of pure water "H_s" in the tank. With this condition, no water is flowing, since the system has reached a static position. Assume that, after the static position has been reached, a section of the pipe is cut off, say "A" amount. Now, the mixture of air and water in the column no longer balances the head of pure water in the tank and the result is a flow of water up the vertical column. The actuating force is equal to the unbalanced force of the column of mixture due to deducting "A." This actuating force is equal to the pressure exerted by the head of pure water H_s (submergence) less the pressure exerted by the head of the mixture H_1 (lift) + H_s (submergence).

Terms

H_z = Distance from ground level to point of discharge = Lift above ground in feet.

H_n = Distance from the water level to the ground level when the well has been allowed to stand for some time without pumping = Static lift in feet.

H_d = Distance from the water level when the well is pumping the desired quantity of water to the water level when the well is not pumping = Drawdown at required water capacity in feet.



H_1 = Distance from pumping level to point of discharge = $H_z + H_n + H_d$ = Total lift in feet.

H_m = Distance from entrance of air into discharge pipe to the static or normal water level = $H_d + H_s$ = Starting submergence in feet.

H_s = Distance from entrance of air into discharge pipe to the pumping water level = Working submergence in feet. This factor is often expressed as per cent submergence which is

$$\frac{100\,H_s}{H_s + H_1}$$

*Courtesy, Ingersoll-Rand Co.

Data Used in Air Lift Calculations

Quantity of Air Required

$$V_a = \frac{H_1}{C \log_{10} \frac{H_s + 34}{34}}$$

in which

V_a = cubic feet of free air per gallon of liquid.
H_1 = total lift in feet.
H_s = working submergence in feet.
C = factor varying with submergence; given below.

Submergence	Value of C outside air line	Value of C inside air line
75%	366	330
70%	358	322
65%	348	306
60%	335	285
55%	318	262
50%	296	238
45%	272	214
40%	246	185
35%	216	162

Submergences

Lift in Feet	Customary Allowable Submergence Percentage	Best Submergence Percentage
20 to 125	50 to 70	65-70
125 to 175	40 to 65	60-65
175 to 250	40 to 60	55-60
250 to 350	37 to 55	50-55
350 to 650	37 to 50	45-50
650 to 750	35 to 45	40-45

Size of Discharge Pipe

$$d = 13.54\sqrt{\frac{Q}{v}}$$

in which

d = inside diameter of pipe in *inches.*
Q = Volume of the mixture of air and water in cu. *ft.* per min.
v = velocity of mixture in pipe in *ft.* per min.

With a straight pipe the best discharge velocity of the mixture of air and water for lifts from 40 to 200 ft. varies from 2000 ft. per min. at 35% submergence to 700 ft. per min. at 70% submergence.

With a tapered pipe the best discharge velocity is 1400 ft. per min. at 35% submergence and 550 ft. per min. at 70% submergence. The best velocity for the mixture of water and air at the entrance to the bottom of the discharge pipe is 800 ft. per min. at 35% submergence and 450 ft. per min. at 70% submergence.

Starting Pressure

$P_s = 0.434\ Hm$

in which

P_s = starting pressure in lbs. per sq. in.
Hm = starting submergence in feet.

Working Pressure

$P_w = 0.434\ H_s + P_f$

in which

P_w = working pressure in lbs. per sq. in.
H_s = working submergence in feet.
P_f = friction drop in air line from the compressor to the foot piece in lbs. per sq. in.

Horse-Power and Electrical Data

(a) 1 H.P. = 0.746 KW. = 746 watts.

(b) Brake H.P. = $\frac{\text{KW. input}}{0.746} \times$ motor efficiency.

(c) Water H.P. = $\frac{\text{g.p.m.} \times \text{head in ft.}}{3960}$.

(d) H.P. to lift water = $\frac{\text{g.p.m.} \times \text{head in ft.}}{3960 \times \text{pump efficiency}}$.

For "Sewage and Sludge Pumping" (See Sewerage Section)

(This chart from Peerless Pump Bulletin of Ford Machinery Corp.)

RATING AND SAMPLING WELLS BY AN IMPROVED METHOD

By PAUL F. HOWARD, M.S.*

Consulting Engr., Boston, Mass.

It is oft-times desired and of importance to ascertain the quantity and quality of water yielded by an individual driven well connected to other wells of a water system. Experience has shown that analyses of samples of water taken from individual wells by means of a hand pitcher-pump give false and meaningless results, especially in relation to the iron content. Likewise the yield of an individual well by means of separate pumping furnishes but little if any information as to the yield of the individual well when ganged together into a common system.

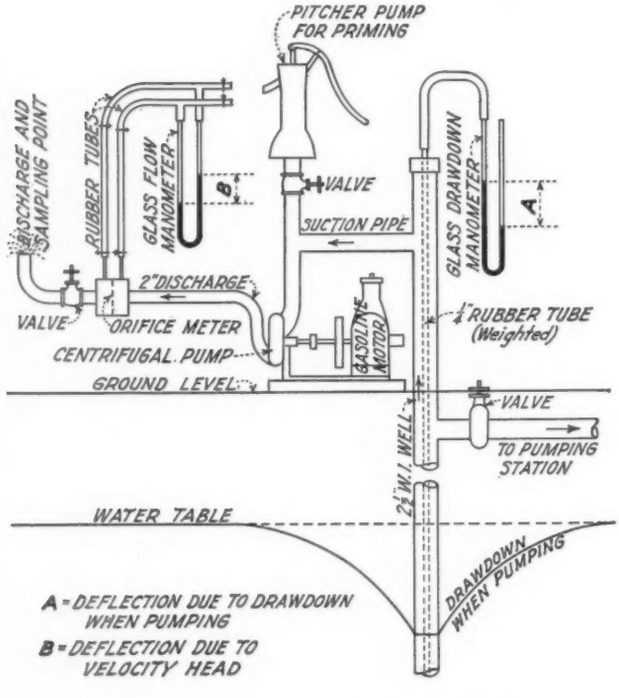
The writer's firm was engaged to investigate a water supply from about 90 driven wells. During the course of the work it became desirable to determine the yield of each individual well and the iron content of the water from each individual well under normal operating conditions. This was done by a device which we have called a Well Rater and Sampler. The device (see cut) was connected to the top of the well by a 2½ inch wrought iron pipe about 2½ feet long. At this point a 1¼ inch centrifugal pump was connected by the proper fittings and discharged through a 2 inch pipe. On the suction pipe a hand pump was attached to prime the pump. A 2 inch orifice flow meter was inserted in the discharge line and by means of a manometer the rate of flow was determined. The amount of the draw-down of the well, when connected to the well field, was determined by means of a mercury U tube connected to a small tube attached to the well cap, the tube extending into the well to a depth sufficiently great so that the end was at all times below the level of the water-table outside of the well.

Before the Well Rater and Sampler was connected to the well the permanently installed valve on the suction line was closed. After the device was connected this valve was opened and the well was observed under actual working conditions—i.e., while it was being pumped along with the other wells by the large pump in the pumping station. The drawdown was revealed by the reading of the manometer connected to the tube in the well and recorded. Thereafter, the permanently installed valve was closed and the centrifugal pump started, the rate of pumping being controlled by a valve on the discharge line. As the discharge increased the drawdown increased, thus producing a deflection on the manometer. When the manometer reading was the same as that already observed under the actual working conditions, as just described, the output of the well was assumed to be the same. The quantity being pumped was then determined by observing the deflection of the flow manometer on the pump discharge line. The results represented the actual amount of water that the well was contributing from the field as a whole when under *actual* pumping conditions. Samples of water for analyses, then taken at the point of discharge, were considered truly representative samples.

By careful operation of the valve at the discharge end of the pipe the yield of the well was brought gradually up to the original yield at the beginning of pumping. Thereby higher velocities than usual or ordinary in the pipe well were provided. Any excess velocities would, of course, free scale, rust and other matter and give false samples. The flow manometer in this particular instance was connected to the 2 inch orifice flow meter. [The liquid used to determine the differential pressure can be of any specific gravity desired depending upon the rate of flow to be measured. The most common is mercury for high flows and carbon tetrachloride, Specific Gravity 1.60, for low flows.]

One side of the mercury U tube was connected to the tube in the well and filled with water from the surface of the mercury to the water level in the well, care being taken to remove all air. The other side of the U tube was left open to the atmosphere.

*Whitman and Howard, Engs., Boston, Mass.



WELL RATER AND SAMPLER

The Hook-Up of the Well Rater and Sampler

A Specific Case

The following specific example will serve as an illustration. After the Well Rater and Sampler had been properly set up and connected to a well the mercury U tube was connected to the tube in the well. There was an initial deflection of mercury of 3 inches which represented a water column of 40½ inches, the distance from the water table to the mercury surface of the U tube. After an equilibrium had been reached the well was connected to the field and the mercury in the U tube deflected an additional amount corresponding in general to the distance the water table dropped outside of the well and specifically to the drop in pressure in the well. In this case the total deflection was 4¼ inches or a difference in deflection of 1¼ inches which equal 17 inches of water as the drawn down within the well.

The well was then shut off from the other wells and the small test pump started. The discharge valve on the pump was then opened slowly, increasing the yield of the well until the drawdown deflection of mercury showed 4¼ inches. After this point was reached the flow manometer was observed to have a deflection of 1⅝ inches of mercury which on this meter represented a flow of 20.1 gallons per minute.

The yield of the various wells in relation to the drawdown was plotted on arithmetic paper and the yield of each well was found to be directly proportional to its drawdown. The yield of the various wells varied from 1 to 25 gallons per minute and the drawdown varied from 5½ to 26 inches.

This device has been made use of in installing new driven well fields. By its use we have been able to predict reasonably well the draw down or vacuum to be expected in a system of driven wells and to eliminate uneconomic wells, which have a low yield in relation to the drawdown. Also with open end wells it has been possible to determine at what yield a well will throw sand sufficiently to result in filling up by sand. The equipment will probably be found to have other uses also.

Acknowledgment—The above paper was presented before the New England Water Works Association, at Providence, R. I., Sept. 19, 1935, and appeared in WATERWORKS & SEWAGE for December, 1935.

ELIMINATING SURGE TROUBLES ON PUMP DISCHARGE LINES*

By D. M. RADCLIFFE

Engineer, U. S. Engineers' Office, Washington, D. C.

The purpose of this article is to relate a practical means of preventing dangerous surges and water-hammer in water service pipe lines.

There are several means of preventing surges in pipe lines, the best known of which is the surge tank. In most water supply systems it is not practical to provide surge tanks and therefore some other means must be employed if excessive surging is to be eliminated.

A common cause of dangerous water-hammer or surge in pipe lines of water supply systems is failure of the electric power input to motor driven pumping units. This sudden stop in pumping sets up a series of pressure waves or surges in the discharge pipe line. Much has been published with respect to water-hammer and its effects on pipe lines, therefore this article will discuss briefly a practical means of eliminating surge or water-hammer conditions. The method described is in satisfactory operation on the Washington Aqueduct in the city of Washington, D. C.

The Dalecarlia Pumping Station is equipped with nine synchronous motor driven centrifugal pumping units of 10 and 20 m.g.d. capacities. Three discharge pipe lines extend from the station to service reservoirs. One is a 48-inch pipe line, 12,350 feet in length with 110 feet working head; one a 36-inch line, 8,900 feet in length with 220 feet working head; one a 36-inch line, 15,950 feet in length with 340 feet working head. Three pumps are connected into each of these three lines.

Following accepted practice quick closing check valves had been installed in each of the pump discharge lines. Electric power failures, which occur several times each year, proved the cause of excessive and dangerous surges of water-hammer in the discharge lines. Records of the surges were taken on high-speed pressure charts and it was found that the maximum surge pressures recorded were 175 per cent above normal working pressure on each line.

Rotary Plug Type Check Valves Installed

After the pumping station had been in opertion for approximately three years, it was decided to install check valves which would reduce to a minimum the loss of head through such valves. The new valves installed are of the rotary plug type and hydraulically operated. These are equipped with an adjustable timing feature to provide means of regulating the speed of closing upon pump shut-down or failure of electric power. Timing tests were made on the new valves to determine, if possible, a closing period which would limit pipe line surges to safe values. A number of closing periods, varying from one second to fifteen seconds, were tried. It was not permissible to employ closing periods in excess of fifteen seconds because a reverse flow of water through the pumps would take place and rotate the units backward at high speed. Since the pumps are not designed for reverse rotation this condition was considered unsafe and time of valve closing was limited to a maximum of fifteen seconds. In the series of closing period tests made, it was found that a five second period produced the best results, but the surge was still 100 per cent above normal working pressure. Unless the check valve can be left open until a surge is dissipated and then closed slowly, it is necessary to close the valve before the first supernormal return wave reaches the station or valve. In the case of the Dalecarlia Station, the first

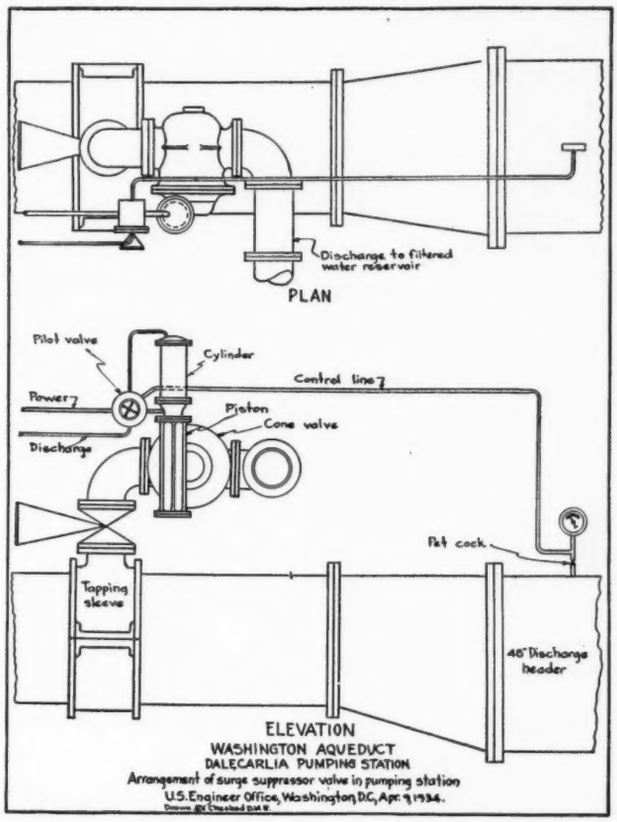


Fig. 2.—Sketch to Show Arrangement of Tapping Sleeve and Surge Relief Valves

*From WATER WORKS AND SEWERAGE, May, 1934.

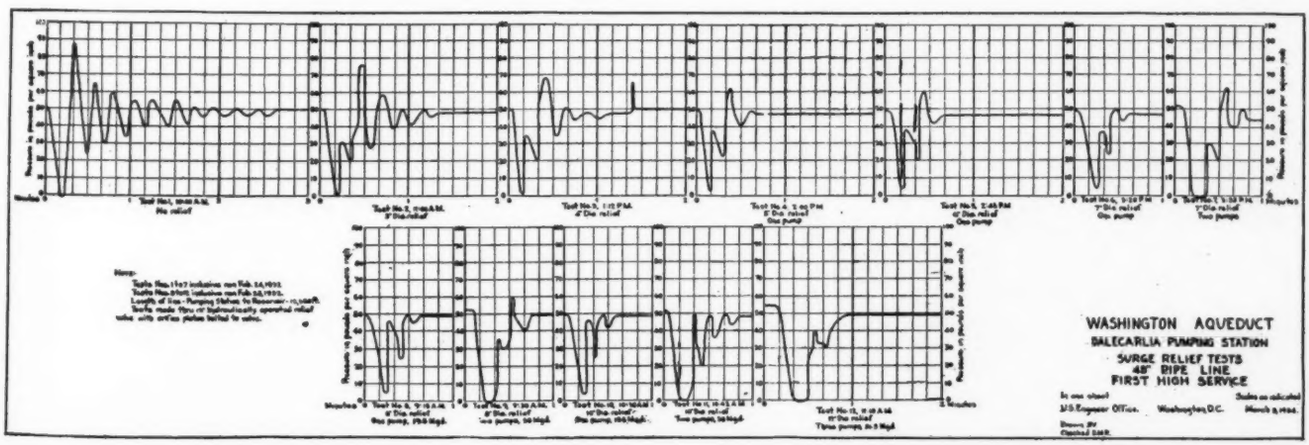


Fig. 1.—Results from Surge Relief Experiments, Employing Various Sizes of Relief Orifice

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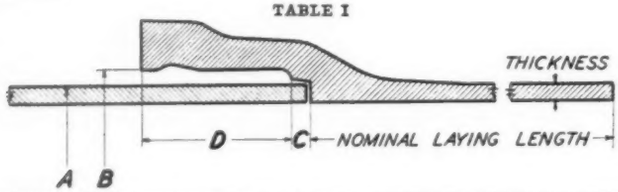
Super-deLavaud Pipe with B&S Joints

Super-deLavaud Pipe with bell and spigot joints is available in all sizes from 3″ to 24″ and in 12-foot and 18-foot lengths. The joint is particularly adaptable for lead, cement, joint compound or rubber ring assembly. The centering ring insures easy alignment and uniform distribution of the jointing material. The process by which this pipe is produced assures concentricity, evenness of metal and freedom from sand or slag inclusions. The bell and spigot joint, made with lead or other jointing materials, shows ample strength to resist pulling apart. If required to meet service conditions, pipe will be furnished with special linings. All Super-deLavaud Pipe with bell and spigot joints are made to meet Federal Specification WW-P-421. Write for descriptive booklet.

TABLE I



Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length			
			12-Foot Length		18-Foot Length	
			Weight of Pipe Pounds	Weight Per Foot Including Bell	Weight of Pipe Pounds	Weight Per Foot Including Bell
3	150	.33	140	11.8		
3	250	.36	155	12.8		
4	150	.34	195	16.4	285	15.9
4	250	.38	220	18.4	325	17.9
6	150	.37	315	26.3	460	25.5
6	250	.43	350	29.3	515	28.5
8	150	.42	475	39.4	690	38.3
8	200	.46	510	42.4	745	41.3
8	250	.50	545	45.5	800	44.3
10	150	.47	640	53.3	935	51.8
10	200	.52	700	58.3	1025	56.8
10	250	.57	760	63.3	1115	61.9
12	150	.50	810	67.4	1180	65.6
12	200	.57	905	75.4	1325	73.7
12	250	.62	990	82.5	1450	80.7

Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length			
			12-Foot Length		18-Foot Length	
			Weight of Pipe Pounds	Weight Per Foot Including Bell	Weight of Pipe Pounds	Weight Per Foot Including Bell
14	100	.48	920	76.5	1340	74.3
14	150	.55	1060	88.5	1555	86.3
14	200	.62	1190	99.0	1735	96.3
14	250	.69	1320	110.0	1930	107.3
16	100	.52	1130	94.2	1645	91.4
16	150	.60	1320	110.2	1935	107.4
16	200	.68	1490	124.1	2175	120.7
16	250	.75	1635	136.1	2390	132.7
18	100	.56	1365	113.8	1990	110.6
18	150	.65	1595	132.8	2330	129.6
18	200	.74	1810	150.9	2645	146.9
18	250	.83	2015	168.0	2950	163.9
20	100	.58	1585	132.0	2305	128.0
20	150	.68	1860	155.0	2720	151.0
20	200	.78	2125	177.1	3105	172.4
20	250	.88	2365	197.1	3465	192.4
24	100	.64	2085	173.8	3035	168.6
24	150	.76	2480	206.8	3630	201.6
24	200	.88	2855	237.8	4170	231.6
24	250	1.00	3200	266.8	4690	260.6

Threaded Cast Iron Pipe Centrifugally Cast

Super-deLavaud Cast Iron Pipe is now being manufactured in "iron pipe sizes" with threaded joints to meet the demand for a better and more durable pipe. There are two distinct types of service for which Super-deLavaud Cast Iron Pipe may be used: pressure service for water, gas, steam or similar liquids and gases; and drainage service. Pressure pipe is made to meet the requirements of Federal Specifications WW-P-421 and is supplied in three classes: standard, extra-strong and double-extra-strong. Drainage pipe, used for waste, vent and drain work, is a lighter pipe for use in buildings and elsewhere where a tight screw-coupled joint is needed. Drainage pipe is made to meet the requirements of Federal Specifications WW-P-356.

THREADED CAST IRON PRESSURE PIPE

(Made to meet the requirements of Federal Specifications WW-P-421)

Size Inches	Class	Nominal Length, Feet	Outside Diameter, Inches	Nominal Thickness, Inches	Threads per Inch	Weight per Foot Pounds
3	Standard	12	3.50	.36	8	11.08
	X-strong	12	3.50	.45	8	13.45
	XX-strong	12	3.50	.48	8	14.21
4	Standard	18	4.50	.38	8	15.34
	X-strong	18	4.50	.48	8	18.91
	XX-strong	18	4.50	.52	8	20.29
5	Standard	18	5.56	.40	8	20.22
	X-strong	18	5.56	.49	8	24.40
	XX-strong	18	5.56	.53	8	26.15
6	Standard	18	6.63	.43	8	26.13
	X-strong	18	6.63	.51	8	30.59
	XX-strong	18	6.63	.55	8	32.78
8	Standard	18	8.63	.50	8	39.85
	X-strong	18	8.63	.56	8	44.29
	XX-strong	18	8.63	.60	8	47.22

THREADED CAST IRON DRAIN PIPE

For Waste, Vent and Drainage Service

(Made to meet the requirements of Federal Specifications WW-P-356)

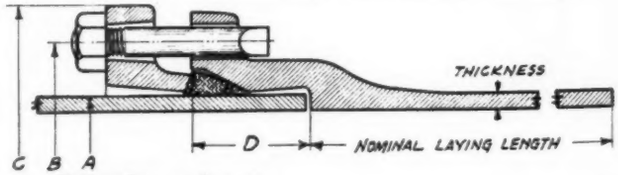
Size Inches	Nominal Length Feet	Outside Diameter Inches	Minimum Thickness Inches	Threads per Inch	Weight per Foot Pounds
3	12	3.50	.26	8	9.41
4	18	4.50	.29	8	13.75
5	18	5.56	.33	8	19.05
6	18	6.62	.38	8	26.22
8	18	8.62	.44	8	39.82

THE U. S. JOINT

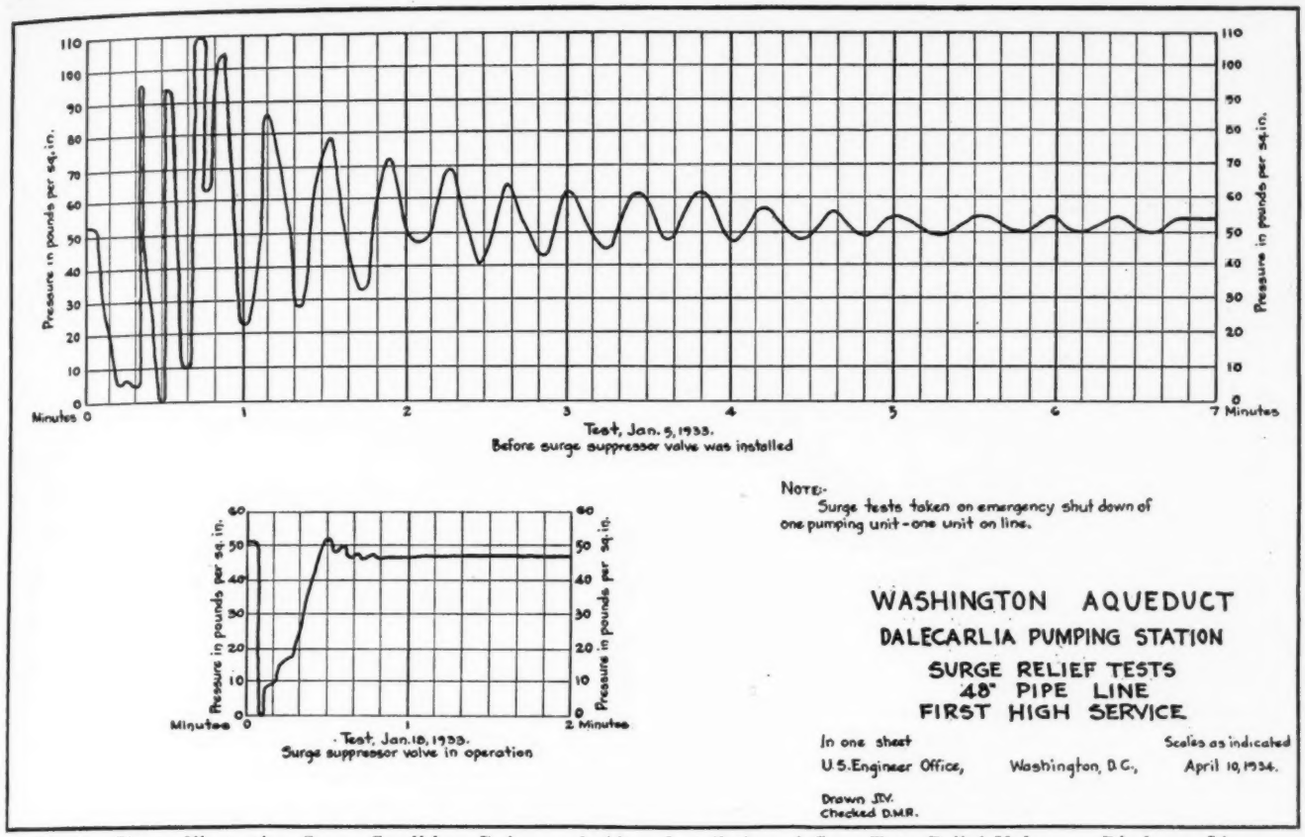
The U. S. Joint embodies the more favorable features of certain other types of mechanical joints and was developed and patented by the United States Pipe and Foundry Company after considerable study and research. It is adaptable to both Super deLavaud Centrifugal Pipe, and to pit cast pipe and fittings and these may be interchanged one with another in the laying of a line without the need of an adapter. The accessories, which consist of follower ring, gaskets and bolts are all interchangeable.

It possesses the following salient advantages:

Write for "U. S. Joint Pipe and Fittings" Catalog.



1. Ruggedness of parts.
2. High resistance to corrosion since all of the joint accessories are of the same material—cast iron.
3. Maximum joint deflection without leakage.
4. Great resistance to the flow of electric currents.
5. Ease of assembly—needs only one wrench.
6. Only one gasket per joint.
7. Excellent qualities as an expansion joint.
8. Tightness under high pressures of gas or water.
9. Connection to plain end existing pipe line without use of adater.


Pressure in pounds per sq. in.
Minutes
Test, Jan. 5, 1933.
Before surge suppressor valve was installed
Test, Jan. 18, 1933.
Surge suppressor valve in operation
Note:-
Surge tests taken on emergency shut down of one pumping unit - one unit on line.
WASHINGTON AQUEDUCT
DALECARLIA PUMPING STATION
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48" PIPE LINE
FIRST HIGH SERVICE
In one sheet
Scales as indicated
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Fig. 3.—Charts Illustrating Surge Conditions Before and After Installation of Cone Type Relief Valves on Discharge Lines

supernormal wave reached the station seven seconds after power failure. The results obtained by valve timing were therefore not considered satisfactory because these valves must protect pipe lines of concrete construction which were not designed to withstand the surge pressures encountered.

Further Studies on Surge Relief

Investigations of several methods of surge suppression in pipe lines were then made. It was decided to provide a relief valve on each pipe header in the pumping station. To make the installation it was necessary to provide an outlet from each of the three pump-discharge lines. This was accomplished by installing "Smith" tapping sleeves (Fig. 2) with 10 inch outlets. A 10-inch gate valve was bolted to each sleeve to provide emergency shut-off. The discharge from each surge relief valve was carried into the filtered water reservoir to prevent waste of purified water.

Before deciding upon size of valves to be used, calculations and field tests were made to arrive at the size of relief required. The field tests consisted of a series of surge tests relieved through different sizes of openings. This was done by providing a 12 inch valved opening on one of the pumping station headers. A series of tests was then made under variable pumping conditions with the several orifice plates bolted on the valve. The valve was of the quick opening, hydraulic type, manually controlled. A signal system was installed to insure proper timing of test valve opening. The field tests included surge relief through openings 2, 4, 6, 8, 10 and 12 inches in diameter. It was found that the 2 and 4-inch openings had very little effect in damping the supernormal surge pressure. The 6-inch opening did not damp the first supernormal wave but did damp out the succeeding waves. The 8-inch opening entirely damped or eliminated all supernormal waves. From the results obtained in the field tests it was decided to install 10-inch surge relief valves on each of the pump discharge lines. The chart (Fig. 1) shows the results of the tests made with the orifice plates under variable pumping conditions.

Automatic Cone Relief Valves Installed

The surge suppressor or relief valves installed are of the hydraulically operated, rotary plug type (Fig. 2), manufactured by the Automatic Cone Valve Company, now a division of the Chapman Valve Company. Since the valves meet open when the pressure drops in the pipe lines it was necessary to supply water pressure for valve operating from an independent source of supply. A 60-gallon residential supply water system was installed to insure an unfailing supply of water pressure to the three surge relief valves. The valves operate in the following manner: the normal pressure of the pipe line operates against a spring diaphragm pilot valve which admits control water pressure to the "closing" end of the hydraulic piston.

This holds the surge relief valve in the closed position. When a power failure occurs, the water in the pipe line flows away from the pumping station causing a subnormal wave in the line. This results in low pressure against the control diaphragm, which allows a spring to operate the pilot valve, which in turn allows high pressure control water to flow to the "opening" end of the hydraulic piston which opens the main surge relief valve. The opening action is very rapid, the entire operation requiring only from 1.5 to 2 seconds. The average duration of the first sub-normal wave in the Washington lines is approximately 8 seconds, thus the surge relief valve is wide open before the first super-normal return wave reaches the station. With the surge relief valve open, all succeeding supernormal waves are dissipated through the open valve. The pipe line now assumes a penstock condition and the surge relief valve must be closed very slowly in order to prevent setting up penstock surges. This is done by limiting the flow of control water to the "closing" end of the hydraulic piston. For successful results it was found that a 2-second opening and 2.5-minute closing of the surge relief valves entirely eliminated water-hammer or surges in the respective pipe lines.

Results

During the period of service since these surge relief valves have been in operation in the Dalecarlia Pumping Station several power failures have occurred. High speed pressure charts indicate, however, that pipe line surges have been entirely eliminated as indicated by typical records pictured in Fig. 3.

THE ELIMINATION OF CHECK VALVE SLAM

By H. K. PALMER*
Los Angeles, Cal.

The slamming of check valves when pumps are stopped constitute a source of annoyance and often of expense to water works or sewage works, and allied institutions. Many check valves have an annoying habit of slamming when it is least expected, while others placed on long lines may close quietly. Too sudden closing may easily cause a rupture in a pipe line, a feature which may be eliminated by inclusion of a large air chamber which will eliminate sudden pressure on the pipe but may cause such an abrupt closing of the valve as to crack the flap.

Check valve slam produced by a surge in the water column causes water hammer, with its consequent damage. When a pump suddenly stops, the water tends to continue in motion due to its momentum, and the gage pressure drops to zero. The force tending to stop the motion of the water is proportional to the static head on the pump and such force produces a negative acceleration in the water column according to the formula:

$$F = Ma$$

where: F = Force producing acceleration; M = Mass of water; a = Acceleration.

Letting: A = Area of pipe, square feet; L = Length of pipe in feet; g = Acceleration due to gravity (32.2); w = Weight of a cubic foot of water (62.4 lbs.); h = Static head on the pump; Hf = Friction head; H = Total head; t = Time in seconds; v = Velocity in pipe:

One may: compute the force producing acceleration as being

$$F = h\,A\,w$$

And, the mass of water is found to be

$$M = \frac{A\,L\,w}{g}$$

Then:

$$h\,A\,W = \frac{A\,L\,w}{g}\,a$$

Or

$$a = \frac{h}{L}\,g \qquad \text{(See Figue 1)}$$

If v is the velocity in the pipe before the pump stops, the time (in seconds) required to bring the water to a stop will be

$$t = \frac{v}{a}$$

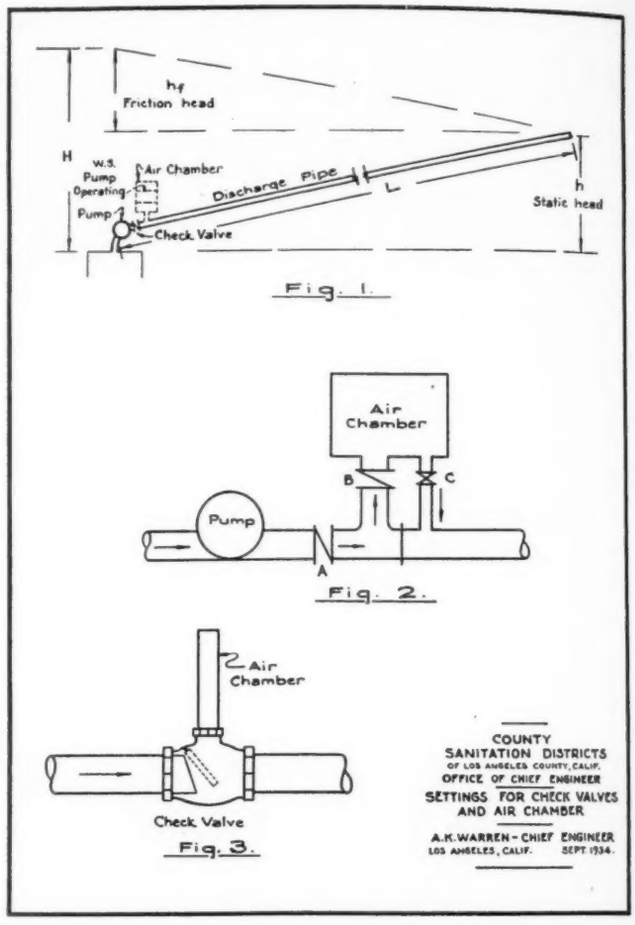
If the flap can come to its seat in (t) seconds or less, it is obvious that the water cannot move backwards and as the flap is moving against the stream it will be cushioned. On the other hand if the flap does not have time to become seated within (t) seconds, the water will start backwards and the valve will close with a slam.

Rapid vs. Slow Closing Checks

It is obvious that what is desired is *a valve that will close rapidly*. One way to accomplish this is to have the valve seat inclined to shorten the distance the flap must move, and another is to use a valve with an extended hinge pin and arm so that the flap can be weighted. This weight prevents the flap from opening fully, causing a small increase in pressure, but accelerates its return movement when the pump stops. On one test in which a four-inch pump was forcing water into a pneumatic tank under 65 pounds pressure, the slam was eliminated by hanging enough weight on the check hinge pin arm to increase the pumping pressure less than one-half pound. This represented one of the most difficult situations for slam elimination because the pump line was short and there was little mass to the flowing water; thus in one controlling formula $a = \frac{F}{M}$, (a) was relatively large; and in the other formula $t = \frac{v}{a}$, (t) was relatively small.

Where it is not practicable to close the check valve in less than time (t), the use of *a slow closing valve* should be considered, but such valves are expensive and must be so designed that the final closure is made very slowly. An air chamber will provide a cushion in case the valve does not close before the flowing water comes to rest and will protect the pipe against excessive pressure. Immediately after the pump stops, the value of the shock absorbing compressed air in such chamber is its cushioning effect, which tends to maintain the gage pressure on the line instead of allowing it to drop to zero. It will thus delay the stopping of the water in the main pipe but the pressure being maintained close to the pump, where the air chamber will normally be placed, produces excessive acceleration in the short length of pipe between the chamber and pump and although the valve will slam violently, the pressure on this section of the pipe will not be excessive. After the valve has slammed the water in the main pipe will slowly come to rest, and then back into the air chamber, the gage showing an oscillation about the static elevation, as a center, with maximum and minimum at approximately $(h + H_f)$ and $(h - H_f)$.

The air cushion in Fig. 1 has purposely been drawn much larger than is recommended in order to illustrate the conditions. If, instead, it consists of a piece of pipe of the same diameter as the discharge pipe and about two or three diameters in height it will not supply enough water to permit any to flow backward through the check valve, thus avoiding a slam and at the same time preventing excessive pipe pressure. A surge will be set up with a maximum pressure of $(H = 2h)$ and minimum $(H = o)$.



Arrangements of Air Chamber Installation to Eliminate Check Valve Slam and Water Hammer

*Chief Draftsman, Los Angeles County Sanitation Districts.

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Water supply lines, river crossings, equalizing mains, outfall lines, water purification piping, low pressure steam lines.

DIAMETERS, WALL THICKNESSES, ETC.

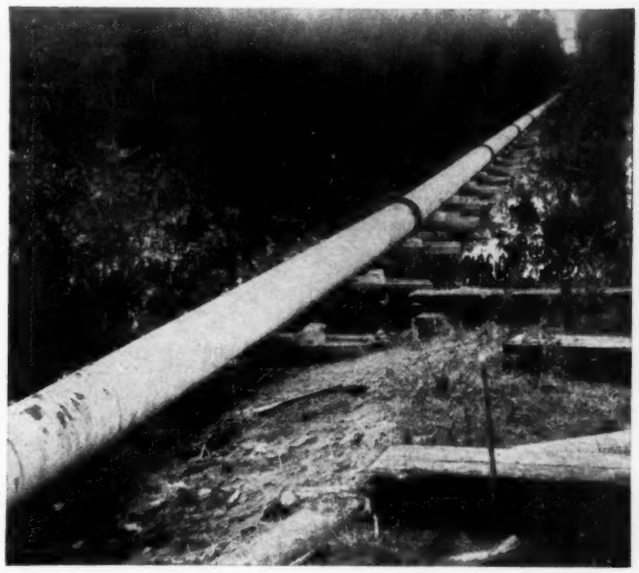
Armco Spiral Welded Pipe is available in diameters from 6 to 36 inches (nominal outside diameter, or with inside diameter equal to nominal). Wall thicknesses range from 7/64 to ½-inch inclusive. Individual pipe lengths up to 40 feet and longer. Standard or special coatings, linings and wraps can be furnished to meet individual requirements.

An actual size view of the ½-inch wall thickness which can be supplied in either ARMCO Ingot Iron or steel.

ADAPTABLE TO VARIOUS JOINTS

You can obtain Armco "Spiral Welded" with ends suitable for Dresser or Victaulic Couplings, or with plain bevelled ends for field welding.

Flanges, spigots or other connections can be provided for joining to any standard pump, valve, pipe or other equipment ordinarily used in the waterworks field.



Water supply line of Armco Spiral Welded Pipe joined with Dresser Couplings to insure freedom from leakage.

STANDARD OR SPECIAL FITTINGS

Elbows, tees, wyes, etc., of standard dimensions can be obtained at nominal cost with Armco Spiral Welded Pipe. In addition, special fittings may be designed and mill fabricated to meet practically any requirement.

Special reducer wye fitting fabricated for waterworks job.

ARMCO

A Successful Arrangement

An air chamber arrangement which has been found to work very successfully is shown in Fig. 2. "A" is the main line check valve, "B" a check valve into the air chamber which should be nearly as large as "A" and set to allow water to enter the chamber. "C" is a gate valve or a plug cock smaller than "B". "C" must be opened or closed by trial until it limits the flow of water from the air chamber enough to prevent slamming of valve "A," and thereafter left in that position. The limited supply to the pipe damps out the surge, yet check valve "B" is large enough to admit a full stream to the air chamber and thus prevent excess pressure on the return flow.

To correct slam in an existing check valve, an air chamber can be built into the cover plate of the valve (Fig. 3). Care must be taken to so adjust the size of such a chamber that sufficient water is returned to close the flap by the time the water comes to rest but not sufficient to produce a slam.

This investigation was made about five years ago by the writer for the Los Angeles County Sanitation Districts and the data obtained applied to the correction of a number of troublesome conditions where valve slam was a problem.

The writer is indebted to E. A. Rutledge of the Rensselaer Valve Company for testing the formulae on many successful water works installations. A. K. Warren is Chief Engineer and General Manager of the Sanitation Districts and A. M. Rawn is Assistant Chief Engineer.

WATER SERVED AT WELL-WATER TEMPERATURE

By WM. M. RAPP

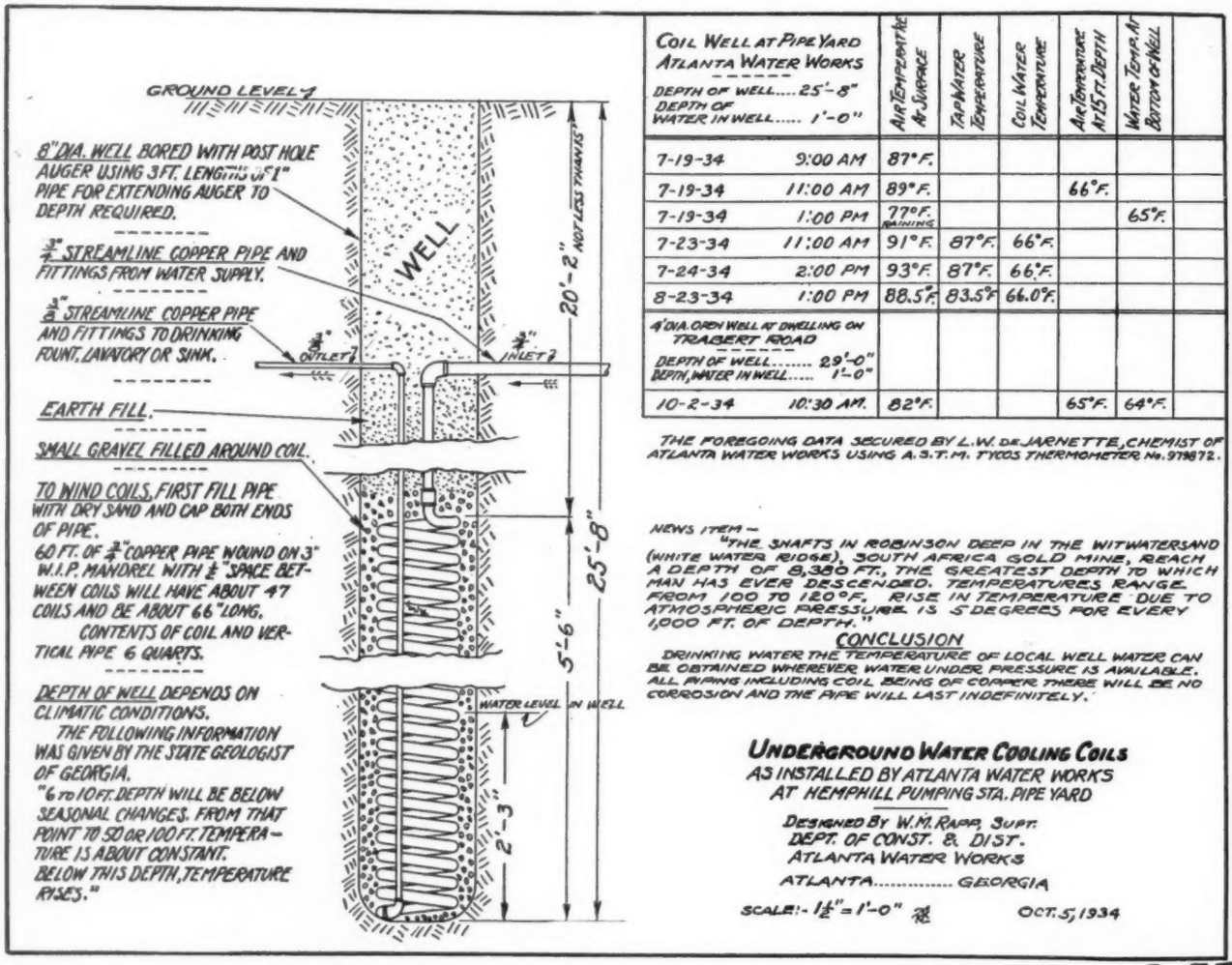
Superintendent of Distribution, Atlanta Water Department, Atlanta, Ga.

A cool drink of pure water on a hot day is very refreshing but few municipalities or private concerns are equipped nor can they afford to supply artificially cooled water to their drinking fountains in parks, on golf links and elsewhere.

The Atlanta Water Department has had two ground water-coolers, similar to the one shown in the accompanying illustration, in service for the past four years and these proved to be so satisfactory that a third has been installed. From the functioning of this last installation the data shown on the sketch was obtained.

When air temperature was 93 degrees F. the tap water temperature from the city mains was 87 degrees F., but the temperature of the water from the depth-cooler was 66 degrees F. A check up against water temperatures in wells in the vicinity showed that the warm tap water, after passing the copper coils of the earth cooler, was the same temperature as waters in the wells.

The accompanying sketch tells its own story of how the coolers are constructed and the results obtained.


GROUND LEVEL
8" DIA. WELL BORED WITH POST HOLE AUGER USING 3 FT. LENGTHS OF 1" PIPE FOR EXTENDING AUGER TO DEPTH REQUIRED.
¾" STREAMLINE COPPER PIPE AND FITTINGS FROM WATER SUPPLY.
¾" STREAMLINE COPPER PIPE AND FITTINGS TO DRINKING FOUNT, LAVATORY OR SINK.
EARTH FILL.
SMALL GRAVEL FILLED AROUND COIL.
TO WIND COILS, FIRST FILL PIPE WITH DRY SAND AND CAP BOTH ENDS OF PIPE.
60 FT. OF ¾" COPPER PIPE WOUND ON 3" W.I.P. MANDREL WITH ¾" SPACE BETWEEN COILS WILL HAVE ABOUT 47 COILS AND BE ABOUT 66" LONG.
CONTENTS OF COIL AND VERTICAL PIPE 6 QUARTS.
DEPTH OF WELL DEPENDS ON CLIMATIC CONDITIONS.
THE FOLLOWING INFORMATION WAS GIVEN BY THE STATE GEOLOGIST OF GEORGIA.
"6 TO 10 FT. DEPTH WILL BE BELOW SEASONAL CHANGES. FROM THAT POINT TO 50 OR 100 FT. TEMPERATURE IS ABOUT CONSTANT. BELOW THIS DEPTH, TEMPERATURE RISES."
WELL
OUTLET
INLET
20'-2" NOT LESS THAN
25'-8"
5'-6"
2'-3"
WATER LEVEL IN WELL

COIL WELL AT PIPE YARD ATLANTA WATER WORKS		AIR TEMPERATURE AT SURFACE	TAP WATER TEMPERATURE	COIL WATER TEMPERATURE	AIR TEMPERATURE AT 25 FT. DEPTH	WATER TEMP. AT BOTTOM OF WELL	
DEPTH OF WELL..... 25'-8" DEPTH OF WATER IN WELL..... 1'-0"							
7-19-34	9:00 AM	87° F.					
7-19-34	11:00 AM	89° F.			66° F.		
7-19-34	1:00 PM	77° F. RAINING				65° F.	
7-23-34	11:00 AM	91° F.	87° F.	66° F.			
7-24-34	2:00 PM	93° F.	87° F.	66° F.			
8-23-34	1:00 PM	88.5° F.	83.5° F.	66.0° F.			
4" DIA. DRIVEN WELL AT DWELLING ON TRABERT ROAD							
DEPTH OF WELL..... 29'-0" DEPTH, WATER IN WELL..... 1'-0"							
10-2-34	10:30 AM.	82° F.			65° F.	64° F.	

THE FOREGOING DATA SECURED BY L. W. DE JARNETTE, CHEMIST OF ATLANTA WATER WORKS USING A.S.T.M. TYCOS THERMOMETER No. 979872.

NEWS ITEM —
"THE SHAFTS IN ROBINSON DEEP IN THE WITWATERSAND (WHITE WATER RIDGE), SOUTH AFRICA GOLD MINE, REACH A DEPTH OF 8,380 FT., THE GREATEST DEPTH TO WHICH MAN HAS EVER DESCENDED. TEMPERATURES RANGE FROM 100 TO 120° F. RISE IN TEMPERATURE DUE TO ATMOSPHERIC PRESSURE IS 5° DEGREES FOR EVERY 1,000 FT. OF DEPTH."

CONCLUSION
DRINKING WATER THE TEMPERATURE OF LOCAL WELL WATER CAN BE OBTAINED WHEREVER WATER UNDER PRESSURE IS AVAILABLE. ALL PIPING INCLUDING COIL BEING OF COPPER, THERE WILL BE NO CORROSION AND THE PIPE WILL LAST INDEFINITELY.

UNDERGROUND WATER COOLING COILS
AS INSTALLED BY ATLANTA WATER WORKS AT HEMPHILL PUMPING STA. PIPE YARD

DESIGNED BY W. M. RAPP, SUPT. DEPT. OF CONST. & DIST. ATLANTA WATER WORKS
ATLANTA..... GEORGIA
SCALE:- 1½" = 1'-0" OCT. 5, 1934

S-75

Underground Water Cooling Scheme of Atlanta Water Department

PRACTICAL HYDRAULICS*

By P. S. WILSON
Glen Ridge, N. J.

I. The Sharp Crest Weir

The so called Sharp Crest Weir is a very useful device for the measurement of water flowing in open channels or streams. A knowledge of the few simple rules governing the design and use of weirs will make it possible to measure the flow of water shed streams contributing to reservoirs, to estimate the overflow or leakage of dams and to make other measurements of use to the water works operator.

By a Weir is meant a bulkhead or dam over which the water flows, or more particularly, a notch in the top of such a structure through which the water flows. As shown in the illustration (Fig. 1), it usually consists of a rectangular notch and it is then known as a Rectangular Weir.

The Crest of a weir is the bottom of the notch, the level to which the water must rise before any can flow over. It is the edge or sill over which the water flows. A weir is a Sharp Crest Weir when the bottom edge of the notch, or the crest, is constructed so as to be as sharp as possible, flush with the upstream face of the dam, and with the opening beveled or enlarged on the downstream side so that the stream of water as it passes through the opening will only touch the crest along one sharp edge, as shown in Fig. 2. In the laboratory the crest is kept as sharp as a knife edge. In practice the edge of a metal plate or angle iron, as shown in the illustration, is usually satisfactory unless extreme accuracy is desired. The upstream face of the weir should be vertical, and of course the crest should be exactly horizontal.

The Head on a weir is the difference in elevation between the crest of the weir and the surface of the water in the pool upstream from the weir. With any given weir there is a fixed relation between the head and the amount of water being discharged, thus by measuring the head the discharge may be determined from the formula or table which applies to that particular form of weir in use.

The relation between the head and the discharge of a weir is different with different forms of crest and different shapes of notches. Different formulas must be used with such different weirs. The reason for making a weir sharp crested is that by so doing a weir can be built which can be used for the measurement of water without the necessity for making special tests to determine what the formula is. The formula for rectangular sharp crest weirs is known, and it has been found easier to reproduce standard conditions by the use of the sharp crest design than with most other forms. Most weirs built for the measurement of water are therefore constructed as sharp crest weirs.

Weir Formulas

One of the most commonly used formulas for use with rectangular sharp crest weirs is known as the Francis formula, named for its originator, Mr. J. B. Francis, who performed extensive experiments on weirs at Lowell, Mass., in 1851. This formula is as follows:

$$Q = 3.33 \times L \times h \times \sqrt{h}$$

In this formula:—

Q = Discharge of the weir in cubic feet per second.
L = Length of the weir crest in feet.
h = Head on the weir in feet.
$\sqrt{h}$ = The square root of the head in feet. The square root of the head is the number which, multiplied by itself, equals the head.

($h \times \sqrt{h}$ is often expressed as $h^{3}/^{2}$, but it is more readily computed if considered in the form given above.)

Example: A sharp crest rectangular weir is 5.00 feet long and has a head of 0.42 feet (5 inches) on it.

(The square root of 0.42 is 0.65, because $0.65 \times 0.65 = 0.42$.)

$Q = 3.33 \times 5.00 \times 0.42 \times 0.65 = 4.55$ cu. ft. per second.

The Francis formula given above is most accurate for heads between about 0.30 feet and 2.00 feet. A small error in determining the head makes such a large error in the discharge at very low heads, that for most practical purposes this formula is sufficiently accurate at all heads up to about 2.00 feet, and it is fairly accurate for higher heads also. The great advantage of the Francis formula is the fact that it is much simpler to compute than most of the others. The principal other formulas are known as the Bazin formula, the Fteley and Stearns formula and the Rehbock formula. A complete treatise may be referred to for the details of these other formulas.

For convenience the results of the computations from a weir formula may be arranged in a table, as shown in Table I. The discharge read from the table may be multiplied by the length (in feet) of any sharp crest weir to obtain the discharge.

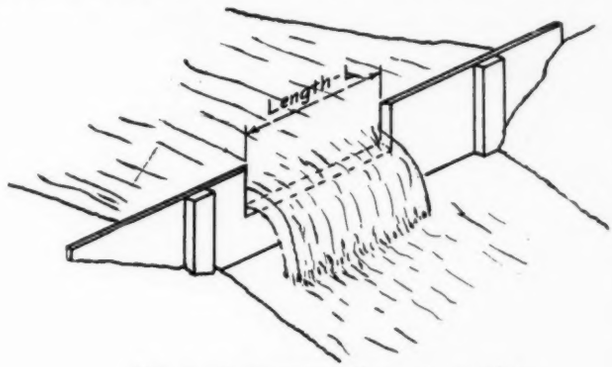


Fig. 1—Rectangular Sharp Crest Weir

TABLE I—DISCHARGE OF A SHARP CREST WEIR PER FOOT OF LENGTH BY THE FRANCIS FORMULA

Head Expressed in Feet	Head Expressed in Inches	Discharge per Foot of Length of Weir Expressed in Cubic Feet per Second	Discharge per Foot of Length of Weir Expressed in Gallons per Minute
.01	1/8	.0033	1.5
.02	1/4	.0094	4.2
.03	3/8	.0173	7.8
.04	1/2	.0266	11.9
.05	5/8	.0372	16.7
.06	3/4	.049	22.0
.07	7/8	.062	27.7
.08	1	.075	33.8
.09	1 1/8	.090	40.4
.10	1 1/4	.105	47.2
.12	1 1/2	.138	62.
.14	1 5/8	.175	78.
.16	1 7/8	.213	96.
.18	2 1/8	.254	114.
.20	2 3/8	.298	134.
.22	2 5/8	.344	155.
.24	2 7/8	.392	176.
.26	3 1/8	.441	198.
.28	3 3/8	.49	222.
.30	3 5/8	.55	246.
.32	3 7/8	.60	271.
.34	4 1/8	.66	296.
.36	4 3/8	.72	323.
.38	4 1/2	.78	350.
.40	4 3/4	.84	378.
.42	5	.91	407.
.44	5 1/4	.97	436.
.46	5 1/2	1.04	467.
.48	5 3/4	1.11	497.
.50	6	1.18	530.
.55	6 5/8	1.36	610.
.60	7 1/4	1.55	690.
.65	7 3/4	1.75	780.
.70	8 3/8	1.95	870.
.75	9	2.16	970.
.80	9 5/8	2.38	1070.
.85	10 1/4	2.61	1170.
.90	10 3/4	2.84	1270.
.95	11 3/8	3.08	1380.
1.00	12	3.33	1500.

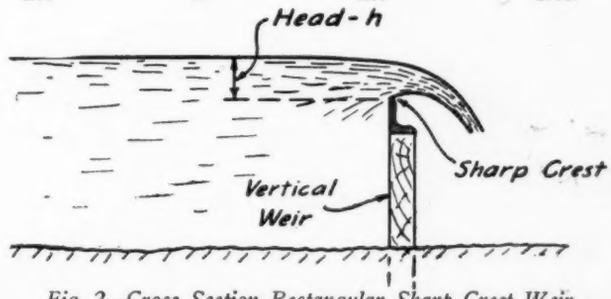


Fig. 2—Cross Section Rectangular Sharp Crest Weir

(Continued on page 364)

*From WATER WORKS AND SEWERAGE.
†Asst. Secy., American Water Works Assn.

JOHNS-MANVILLE

Executive Offices: 22 E. 40th Street, New York, N. Y.

Offices in all large Cities

●

TRANSITE PRESSURE PIPE — TRANSITE SEWER PIPE

FOR YOUR WATER DISTRIBUTION SYSTEMS - - -

TRANSITE PRESSURE PIPE will reduce your Operating, Maintenance and Installation Costs—assure permanently efficient, economical water transportation through the years!

You save all ways when you install Transite Pressure Pipe—for in addition to low first cost and rapid, economical installation—it is remarkably resistant to all the destructive agencies encountered in service. Being non-metallic, Transite is entirely unaffected by electrolysis and tuberculation—the internal corrosion that cuts down flow rates and increases pumping costs—and it is highly resistant to all forms of corrosion.

Manufactured in a wide range of sizes—from 2 to 36 inches inclusive—and in pressure classes of 50, 100, 150 and 200 lbs., it is composed of an intimate mixture of asbestos fibres and cement, formed under tremendous pressure, on a polished steel mandrel, into a tough, dense, homogeneous structure of great strength and uniformity.

TRANSITE CANNOT TUBERCULATE

The smooth interior surface imparted to Transite Pipe by the mandrel on which it is made offers minimum resistance to the flow of water. Numerous tests have proved that the conservative minimum flow coefficient for Transite lines in service is C=140. Some outstanding Water Works authorities report coefficient values on asbestos-cement pipe from 142 to as high as 165.

W. S. Pardoe, Professor of Hydraulic Engineering, University of Pennsylvania reported in an article "Tests of Cement-Asbestos Pipe" (Engineering News-Record, Jan. 28, 1926): "These

Because it is immune to tuberculation, wherever used, Transite Pipe assures an abundant supply of water through the years with low pumping costs.

Transite's remarkable resistance to all forms of corrosion, due to its asbestos-cement composition, assures long life and low maintenance costs.

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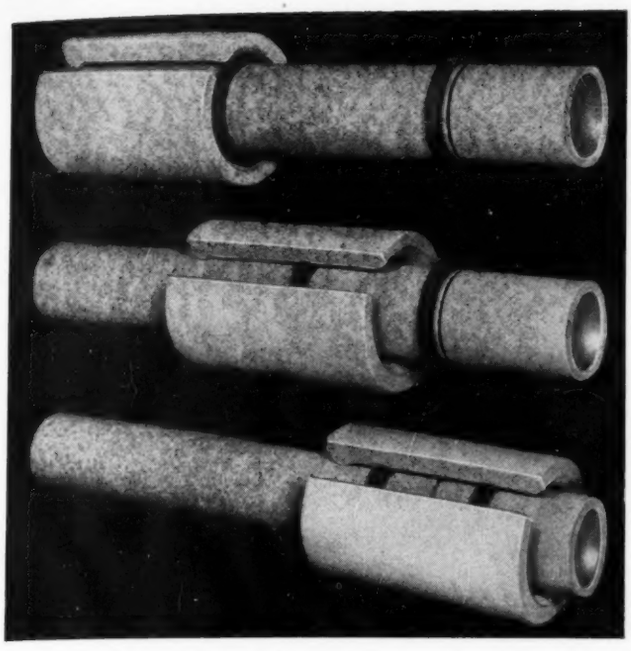


In the above illustration of the Simplex Coupling, the Transite sleeve has been cut to show how the rubber rings are compressed between the sleeve and the pipe. Top: rings and sleeve at start of operation. Center: sleeve pulled over one ring. Below: final position, sleeve centered over joint.

figures indicate that the cement-asbestos pipe will discharge 15% more than clean cast-iron and 45% more than slightly tuberculated cast-iron pipe."

High coefficient values such as these are a permanent feature of Transite Pipe—because, being non-metallic, Transite *cannot tuberculate!* The interior wall remains smooth indefinitely—its initial high delivery capacity is permanently maintained. This assures virtual freedom from excessive pumping costs, reduced pressures and the expense and inconvenience of periodic cleaning.

HIGHLY RESISTANT TO CORROSION

One of the important advantages of Transite's asbestos-cement composition and unusually low free-lime content is its high resistance to external corrosion. Practically unaffected by all active agents in the strength encountered underground, Transite assures large economies in maintenance even when laid under conditions that rapidly destroy other materials.

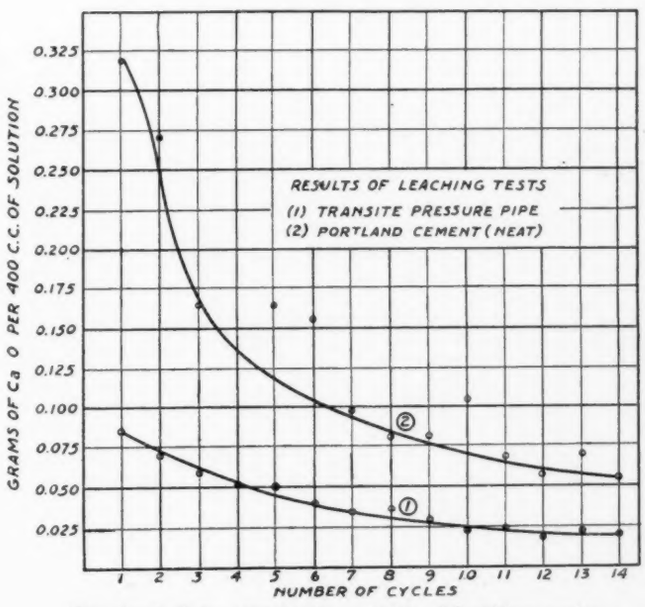
Although there is a certain amount of free lime in ordinary neat cement which may be affected by corrosion, in Transite this free lime is converted into insoluble silicates by a special curing process—thereby greatly increasing its natural chemical stability.

Thousands of installations of asbestos-cement pipe all over the world, laid in all kinds of soil and carrying all types of water, attest to Transite's exceptional resistance to corrosion, its low maintenance cost and permanent efficiency.

LOWER INSTALLATION COSTS

Savings in installation costs with Transite Pipe begin at the very outset. Because of its long 13-foot lengths, relatively light weight and speed of assembly, it is rapidly, economically installed, even by unskilled workmen. More footage may be carried per truck load, fewer men are required for every handling operation and no mechanical equipment is required except for the very largest sizes.

The ease and speed of assembly of the Simplex Coupling used in Transite Pressure Pipe lines is one of the major factors contributing to installation savings. Consisting of a Transite sleeve and two rubber rings, these bottle-tight joints are easily assembled in much less time than that re-



The chart above represents a series of leaching cycles for both pulverized Transite Pipe and neat cement. The small amount of free lime extracted from Transite indicates that for all practical purposes it may be considered insoluble—one of the major factors responsible for its unusual resistance to soil corrosion.

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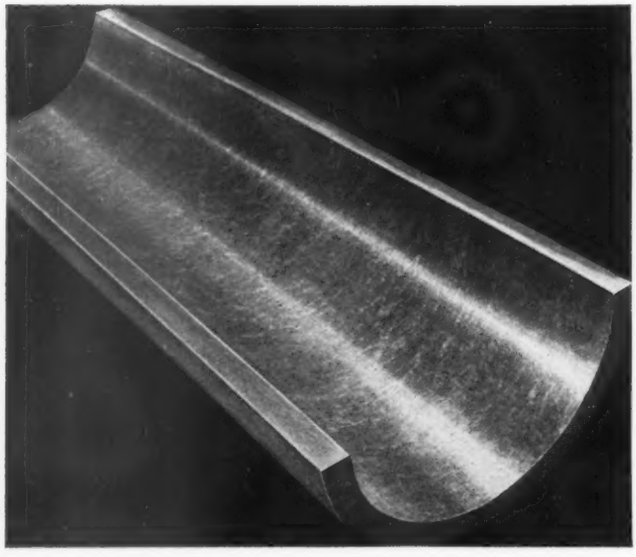
quired by ordinary types of joints. It is not necessary to maintain heating equipment at various points on the job, for the Simplex Couplings are assembled cold just as they are received from the factory—a simple hydraulic coupling puller is the only tool required.

Not only do these couplings permit faster installation and tight joints, but they also provide a desirable flexibility in the line to accommodate ground movement and prevent breakage. Furthermore these flexible, bottle-tight joints permit laying the pipe on long curves without the use of special fittings.

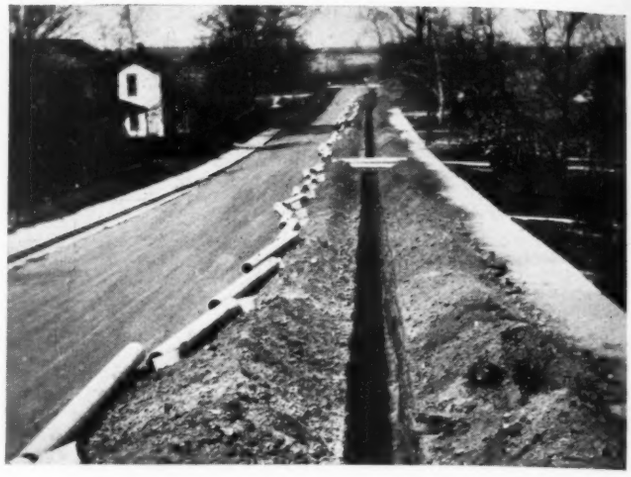
Because of the tough, dense structure of Transite Pipe, it may be drilled and tapped perfectly with standard tapping tools and methods. The deep, clean threads are strong and firm. They provide perfect seating for threads on corporation stops and eliminate leakage at these points.

LOWER MAINTENANCE COSTS

Because Transite Pipe is absolutely immune to tuberculation and electrolysis and highly resistant to all forms of soil corrosion, it provides the best assurance of permanent freedom from cleaning expense, shutdowns and costly renewals. Bottle-tight Simplex Couplings minimize underground leakage and prevent the breaks in mains due to undermining of pipe by joint leakage.



Because Transite is non-metallic, its original smooth interior surface remains permanently unaffected by the destructive, choking effects of tuberculation.



The absence of large bell holes at joints permits the use of narrow, less expensive trenching as is well illustrated by this installation of 6" Transite Pipe.

LOWER PUMPING COSTS

Added to the substantial savings in installation and maintenance are the even greater savings in pumping costs, due to the constant, unchanging high delivery capacity of Transite Pipe, and the extra advantage of bottle-tight joints that prevent wasted water and reduced pressure due to leakage.

And yet, with all these points of superiority, Transite Pipe costs no more, installed, than other types of water pipe.

WRITE FOR COMPLETE DETAILS

For further information on how this modern, permanent water carrier can save you money through the years, write for the free, 36-page, Transite Pressure Pipe Brochure, TR-11A. In addition to complete details on how Transite Pipe will cut your installation, maintenance and operating costs, this illustrated brochure contains excerpts from the Underwriters' Laboratories Report on Transite Pipe, the unbiased opinions of scores of users throughout the country and a wealth of other information vitally important to everyone interested in the more efficient operation of water distribution systems. Ask, also, for the interesting set of Hydraulic Tables based on Hazen and Williams figures, which demonstrate the effect of tuberculation on pumping costs through five to twenty years of service.

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AND IN YOUR SEWAGE DISPOSAL SYSTEMS - - -

TRANSITE SEWER PIPE will increase the efficiency of your system and reduce expense to an absolute minimum!

Manufactured under extreme pressure in the same manner as Transite Pressure Pipe, and made of the same permanent, non-metallic minerals—asbestos fibre and cement—Transite Sewer Pipe is establishing an enviable record for economy and efficiency in sewage disposal systems. Furnished in a wide range of sizes—from 4 to 36 inches inclusive, and in both single and double strength, its many outstanding advantages over ordinary sewer pipe set it apart as being the ideal material for this service.

LONG LENGTHS, LIGHT WEIGHT REDUCE INSTALLATION COSTS

The long 13-ft. sections in which Transite is furnished eliminate the difficulties in installation and maintenance common to ordinary short length sewer pipe. Strong, durable, yet comparatively light in weight, these long sections cut handling costs to a minimum. More footage may be carried per truck load to the trench, fewer men are required to install the pipe and no mechanical equipment is needed except for the very largest sizes. These long lengths reduce the number of joints in the line (only 1/3 to ¼ as many joints as with ordinary short length pipe) and thus save considerable time and labor.

Transite, the corrosion-resistant, asbestos-cement sewer pipe, answers every requirement of efficient sewerage service. Its long 13-ft. lengths make laying to exact grades a quicker and more accurate job. And the tight joints employed minimize infiltration.

In addition, long lengths are more easily laid to a line and resist the tendency to slip out of alignment; therefore, they greatly facilitate laying the pipe to an accurate grade.

TIGHT SLEEVE JOINTS REDUCE INFILTRATION

The poured sleeve joints used in Transite gravity flow lines reduce infiltration to a minimum and with this type of joint there is no bell to break off—the sleeve extends over both lengths of pipe, providing twice the flexibility possible with other types of joints.

The ends of all pipe and the inside of all joint sleeves are *double*-primed at the factory with a specially developed primer that assures greatest adhesion between pipe and compound.

The jointing compound used is the highest quality, unfilled asphalt. It is strong, flexible, easily poured and is not subject to cold flow. Unaffected by temperature changes, this compound provides strong, tight joints that minimize root growth, and the infiltration of ground water and silt that cuts the sewage-carrying capacity of ordinary pipe.

The Simplex Couplings used on Transite force mains provide a rapidly installed, permanently bottle-tight joint that eliminates leakage.

REDUCED MAINTENANCE COSTS

Transite's unusual resistance to all types of corrosion—inside, outside and all the way through—has been proved by a large number of installations serving under a wide variety of conditions. It is virtually unaffected by the action of hydrogen-sulphide gas and other destructive agencies found in sewage. In Transite, the free lime found in ordinary cement products is converted into insoluble silicates, thereby greatly increasing the natural permanence and corrosion-resistance of this asbestos-cement pipe. Its smooth interior surface gives a higher sewage flow and minimizes the labor cost of flushing.

For complete details about this modern sewer pipe write to Johns-Manville, 22 E. 40th Street, New York, N. Y.

JOHNS-MANVILLE JM PRODUCTS

II. The End Contractions of a Weir

There are two methods of constructing the ends of the weir. The first of these is shown in Fig. 3 and results in what is known as a weir *with end contractions.* In this design the sharp crest of the weir as formed by the bottom of the notch is continued up the ends of the notch, thus forming sharp edged ends for the weir. The water in flowing around these sharp corners then follows a course very similar to that taken in flowing over the edge of a sharp crest. In flowing around the edge from behind the weir it cannot change direction sharply and it curves inward toward the center of the weir contracting the stream as shown in the illustration.

The other method of designing the ends of the notch is to build it so that it extends the full width of the stream at that point, allowing the sides of the channel to form the ends of the notch and continue upstream at that width for a short distance, at least. An example of this method of construction is shown in Fig. 4. When so built it is known as a weir *without end contractions* because the water in this case flows straight over the crest, the stream continuing full width all the way. The weir thus consists of a simple dam or bulkhead across the channel.

It may readily be seen that if two rectangular sharp crest weirs have the same length and are flowing under the same head, the one that has end contractions (Fig. 3) is not discharging as much water as the weir without end contractions (Fig. 4). It has been found by experimentation that with sharp edged ends and a wide channel above the weir, so that the over-falling stream is fully contracted, the effect on the discharge of the weir is the same as if the length of the weir were reduced by a distance equal to one-tenth (0.1) of the head at each end of the weir.

For example: A sharp crested, rectangular, vertical weir is three feet long and the ends are so constructed that the flow will be fully contracted. If the head is one foot, then the effective length of the weir is reduced by one-tenth of a foot at each end making its effective length (3.0 — O.z) = 2.8 feet—a reduction in capacity of about 7 per cent from the capacity it would have had without end contractions. Failure to make this correction might constitute a rather serious error.

If the head on the same 3 foot weir were only 0.1 foot instead of 1.0 foot (or if the length of the weir were increased to 30 feet with a head of 1.0 feet) then in either case the reduction in effective length would be only about 0.7 per cent which

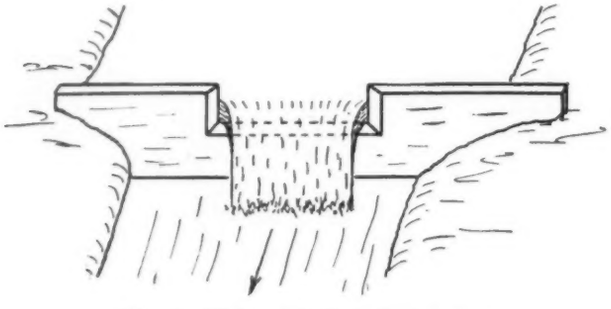


Fig. 3—Weir with End Contractions

would be a negligible error except in the most precise measurements.

It is thus seen that the importance of making the correction for end contractions depends upon the relative head and the length of the weir. If the head is more than one twentieth (5 per cent) of the length then end contractions will require a correction of more than 1 per cent and should certainly be accounted for.

Weirs are seldom operated in practice under a head sufficiently great in proportion to the length that the correction for end contractions is of importance. In such cases it is evident that it does not matter how the ends of the weir are built. Many weirs under practical conditions are built so that they do not have theoretically sharp edged ends and yet neither are they ended against the sides of the stream channel. The ends may merely be formed by the wood or masonry of which the dam bulkhead is built. In such cases we know that there is some end contraction but we do not know how much. Such a weir should be checked up to determine whether the end contraction correction would be of importance if it were complete. If it is found that the relation between the maximum head and the length of the weir is such that the correction would not be

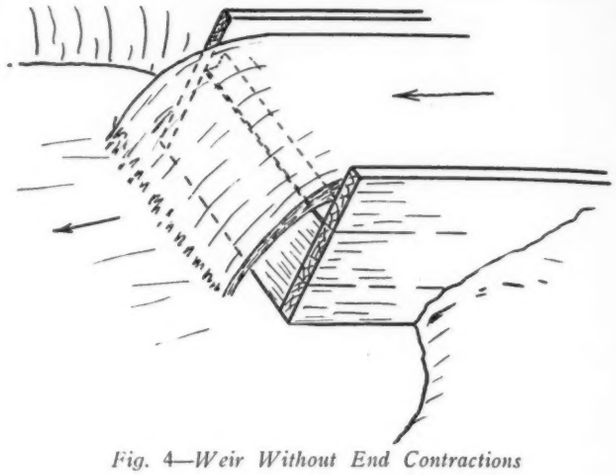


Fig. 4—Weir Without End Contractions

of importance (less than 1 per cent), then we know that it does not matter what it actually is and it can be neglected. It is found that the end contraction correction is of importance then either it must be estimated or else actual measurements of the flow must be made to determine what the correction actually should be. Usually it can be estimated. It is a help in estimating to actually observe the form of the stream during discharge of the weir.

If the relation between the length of the weir and the head is to be such that the end contraction correction will be of importance then the weir should, if possible, be built either with full contractions or with none at all so that the correction will be definitely known.

A weir may be built with a sharp edge on one end only so that the end has a full contraction and so that the other end has no contraction. The correction in such a case is, of course, only one-tenth of the head to be subtracted from the weir length.

III. Measurement of Head on Weirs

The measurement of flowing water by means of a weir depends in turn upon the measurement of the *head* of water on the weir. Having determined the weir formula to be used, depending upon the design of the weir crest, the presence or absence of end contractions and any other fixed condition, the recorded flow then depends upon the head. The head is the single remaining variable quantity. It is the quantity which is actually observed and measured in the field, the desired knowledge as to the amount of water flowing being then computed by the use of the formula, table or diagram. It is assumed in this discussion that the flow over the weir is not affected by backwater from below.

The head on a weir is the difference in elevation between the crest of the weir and the surface of the water in the pool upstream from the weir. Figure 1 is a vertical cross section through a sharp crest weir with water flowing over it under a head indicated by (h). The shape of the upper and lower water surfaces shown in this figure have been determined by measurement and have been found to have forms similar to these, regardless of what the head is, so long as the weir has a sharp crest and a vertical upstream face. Under special conditions at low heads the water may, however, cling to the downstream face of the weir.

Figure 1 shows clearly the fact that in this general case the

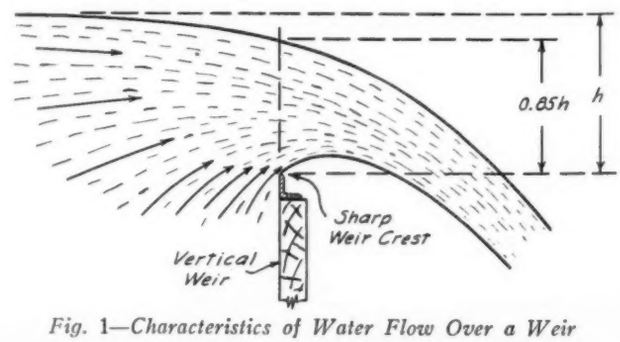


Fig. 1—Characteristics of Water Flow Over a Weir

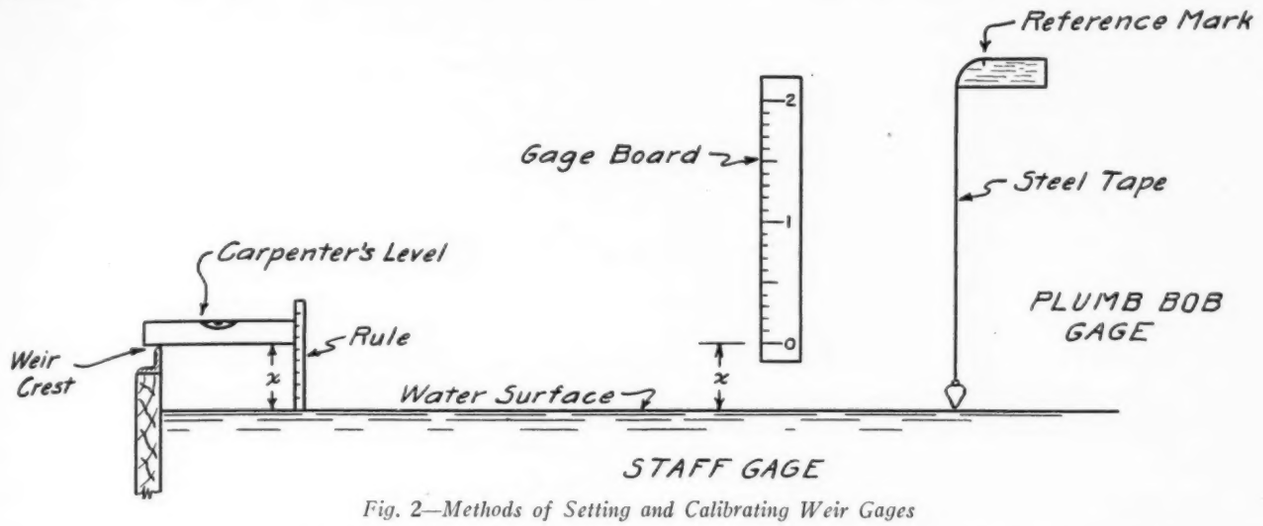


Fig. 2—Methods of Setting and Calibrating Weir Gages

water only touches the crest along the one sharp edge and then leaps free. The arrows showing the converging stream indicate the reason for the shape which the lower surface of the water is found to take. There is one very important fact to be noted from Figure 1—namely, the upper surface of the water starts to curve downward before it reaches the weir. This results in the depth of water at the weir crest actually being only about 85/100ths of "h" (expressed as 0.85h)—the condition which makes it necessary to measure the height of the water surface at some distance upstream from the weir when determining the head. The height of the water surface should be measured at a point located upstream from the weir *a distance at least equal to three times the maximum head* to be encountered.

Measuring Gages

The type and design of gage to be used to determine the water level depends upon the accuracy desired and the conditions under which it will operate.

The Staff-Gage

The simplest and most commonly used type of gage consists merely of a strip of wood or metal with the necessary graduations marked upon it. A section of a carpenter's rule or a surveyor's rod may be used if adequately waterproofed by varnishing. One of the best forms of gage board consists of a vitreous enameled ware metal plate mounted on a wood plank. The graduations and figures are baked into the enamel. Gages such as these, often called staff-gages, if well graduated and carefully read will enable the water level to be determined to within about 0.01 feet, equivalent to about ⅛ inch. This is sufficiently accurate for most purposes other than studies requiring laboratory refinements. One of the greatest disadvantages of this type of gage, however, is the necessity for locating the observer's eye near the water level when taking a reading. This is not always convenient. Care must be taken to read at the true water surface and not the height to which the water surface curves upwards where it wets the gage.

When mounting a staff-gage great care is needed to insure that the zero of the gage is exactly level with the crest of the weir and that it remains so. A small error in this respect will cause a large error in the results, particularly at low heads. Moreover, this error will always be in the same direction and will not tend to correct itself or be compensated for by other errors.

By the careful use of a surveyor's level a gage may be set with sufficient accuracy. If a surveyor's level is not available then the water surface itself may be used in the manner indicated in Figure 2. Choose a time when the water surface is not rising or falling too rapidly and preferably when it is lower than the weir crest. By means of a carpenter's hand level and rule measure the distance (x) down to the water surface from the weir crest. Then measure up from the water surface at the gage location and set the gage zero the same distance (x) above the water level as the weir crest was found to be. Then, afterward, such gages should be regularly checked to be certain that they have not been moved, and that the zero point is correct.

Plumb-Bob Gage

Another form of gage is known as a plumb-bob gage. It consists of a graduated steel tape with a heavy plumb bob on its end. It is used to measure from a fixed reference mark, above water level, down to the water surface. By allowing it to swing slightly the contact of the plumb bob with the water surface may be very accurately noted. This naturally assumes the water surface to be smooth. The plumb-bob gage may be most accurately read if the tape is run over a curved block of wood, mounted permanently above the water, which has the reference mark fixed on its upper surface, as indicated in Figure 2. The zero reading on this type of gage may be determined by measuring down to the water surface from the weir crest as shown in Figure 2 and applying the correction factor determined by a simultaneous reading of the tape.

Chain Gage

A similar type of gage known as a chain gage is often used. For the tape a chain running over a wheel is substituted. With this arrangement the position of a marker attached to the chain above the wheel is read along a horizontal scale. This type of gage is not so accurate as the former and it is not advised for weir readings except in the case of rough work or high heads. It is often used for river heights where accuracy within about 0.05 feet is generally satisfactory.

With all types of gages difficulty is introduced if the water level is disturbed by waves or surges. In the case of the gages above described this can only be overcome by the skill and patience of the operator in mentally averaging the indications while observing them over a short period. Practice can develop considerable skill in doing this.

IV. The Float Gage

Probably the most accurate type of gage, if well designed and constructed, is a float gage. Besides its accuracy it also has other advantages. Difficulty in reading due to waves and surges may be most readily overcome with the float type gage which is readily adapted to the use of an automatic recording mechanism. They may be classified into two types. The simplest type consists of the float with a rigid vertical stem attached to and supported by the float, with an index or pointer at its upper end. The gage reading is obtained from the position of this pointer along a fixed vertical scale. In the other type of float gage the motion of the float is transmitted to some form of indicating or recording mechanism by means of a flexible wire or tape.

The Float

A suitable float is the first essential. It must not become water logged, but must retain its buoyancy. To meet this condition a hollow sheet metal float is generally used, and copper is the preferred material because of its resistance to corrosion. The seams must be well locked and thoroughly soldered. Earthenware floats have been used in sewage or other corrosive liquids. Floats are most often made cylindrical with the axis vertical, in order to fit in a float pipe and. for ease of construction. It is important to have the top and bottom dished outward so that the float cannot be weighted with water on top or lifted by air trapped beneath. The float should have at least three vertical fins projecting a half inch or more from its sides in order to prevent it from clinging to the wall of the float pipe or well. Sometimes a spherical float is used, but in that case its weight, or its counterweight, should be adjusted so that it will float near its middle, in order to gain the maximum sensitivity.

Float Pipe

Floats are usually provided with some form of float pipe or stilling well. This serves two principal purposes—it serves as a guide for the float, and by adjusting the size of the communicating opening into the float pipe the effect of waves or surges upon the gage readings may be reduced. The use of a float pipe also makes it possible to locate the gage a short distance away from the body of water being observed, the level in the float pipe being maintained by a small size connecting pipe. With such an arrangement care must be exercised to avoid air traps in the connecting pipe. The connecting pipe should be made of non-corrosive material and should be provided with convenient means for flushing it out. A float pipe should be provided with a cover, having only a small opening for the wire or tape, in order to prevent objects from falling in and lodging on the float.

If the gage mechanism is light and easily operated, a 5-in. diameter float in a 6-in. float pipe makes a good combination. If a high degree of sensitivity is desired, or if a recorder requiring some power to operate it is used, then a larger float is desirable, a 10-in. float in a 12-in. pipe, or even larger, being often used.

Gage With Rigid Stem

The type of float gage having a rigid stem is the simplest and is also probably capable of the closest reading with accuracy, since the only friction involved in its motion is due to whatever guides may be needed to keep the stem upright and in the correct position with relation to the scale. The effect of this friction in preventing accurate response of the gage to changes in the water level may be largely if not entirely avoided by gently tapping the stem while reading the gage. Gages of this type, if properly designed and constructed, may be read directly to the nearest one thousandth of a foot (0.001 ft.), which is about the best in true accuracy that can be expected from single readings of any type of gage.

An arrangement of this type of gage, which has been used extensively and which is highly suitable for accurate weir head readings, is shown in Fig. 1. In this design a 7-in. float may be used in an 8-in. float pipe. The float stem is a brass rod of about 3/16 in. or ¼ in. diameter, depending on the height. The best scale is made from a graduated brass strip about ⅛ in. thick. It is provided with a continuous projection along its back edge which serves to guide the index or pointer in the correct position for easy reading, and to hold the stem vertically above the float.

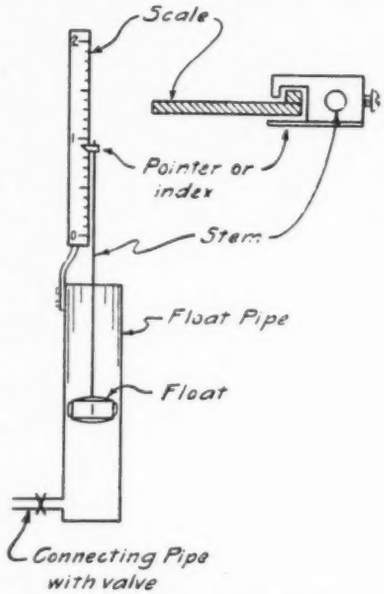


Fig. 1—Float Gage with Stem

Gage With Flexible Wire

The second type of float gage, using a flexible wire or tape, is more adaptable to different arrangements, since the motion is usually converted into a rotary motion by the wheel or drum on which the wire is wound, and thus the readings may be shown on a circular dial, or a recording mechanism may be operated. It is not always so simple to overcome the friction of motion in this type of gage, and for that reason it may not be read quite so accurately unless the float is larger than with the rigid stem type.

A metal wire or tape is necessary for accurate readings in order to avoid changes in length due to stretching or moisture. The wire should be stranded, made from a large number of very small wires braided together, in order to be flexible and withstand frequent bending. Either wire or tape must be of bronze or other non-rusting metal.

The simplest arrangement of this type of gage consists merely of passing the wire over a wheel or pulley and having a counterweight on the end. Reading may then be taken from the motion of a pointer attached to the wire along a fixed vertical scale beside it. A very crude form of such a gage has often been seen on railroad water tanks.

A more usual arrangement in water works practice is to attach the end of the float wire to a drum, around which it is then wound a number of turns. The counterweight is then hung from another wire similarly attached to the drum. By such design slipping of the wire is avoided and the revolution of the drum is a true measure of the change in water level. The drum is then connected to a rotating pointer on a dial or to a recording device. By introducing suitable gearing a wide range of float motion may be shown as only a part of a revolution of the pointer on the dial, or other variations may be introduced changing the scale of readings to suit the conditions and the requirements.

The drum upon which the wire is wound should be provided with spiral grooves to receive the wire so that it will be guided in a single layer and will not wind upon itself, thereby changing the effective diameter of the drum and affecting the accuracy of the gage. If desired, the drum receiving the counterweight wire may be smaller than the drum for the float wire, thereby resulting in a shorter travel for the counterweight where this is of any advantage. The counterweight should not become submerged, since its effective weight would thereby be altered and the submersion of the float changed.

Gage With Tape

If a tape is used it is customary to provide it with uniformly spaced perforations which fall over similarly spaced projecting pins on the drum, thereby preventing slipping. A tape is, of course, not wound around the drum, but merely passes over it once, with the counterweight on the end. The counterweight must then travel through the same range of motion that the float does.

Indicators and Recorders

Many good designs of indicating and recording instruments are commercialy available for use with floats and which are adaptable to different conditions and requirements. Floats may also be utilized similarly to operate transmitters for long distance electrical transmission of gage readings, known as telemeters.

Copper and Health

The effect of copper on health is a subject of such importance to all users of copper and brass and copper sulphate for algae control, that the conclusions in an article read before The New England Water Works Association* are given below:

1. The copper content of domestic drinking water after passing through copper or brass pipe or tubing, even if a slight amount of copper is taken into solution, is not harmful to health. It may indeed be beneficial.

2. All water supplies intended for domestic use after passing through a proper installation of copper or brass pipe or tubing will contain but a small percentage of the permissible copper content, if any at all.

3. The permissible copper content of domestic water based on a consumption of one gallon of water a day should apparently not be greater than 20 p.p.m.

4. It is unlikely that health will be injured by copper because, where the copper content is above 5 p.p.m., the taste of the water will generally be so disagreeable that it will be virtually impossible to drink it.

5. No anxiety need be felt about a proper installation of copper or brass pipe or tubing, because it has been shown that with acid water having a pH value of about 6.5, the copper content is generally only about 0.5 p.p.m., even after standing in the pipe lines for an appreciable length of time.

6. The treatment of reservoirs with copper sulphate to rid them of undesirable microscopic growths has no injurious effect on health.

*Journal N. E. W. W. A., 44: 4, December, 1930.

MAIN LINE METERING OF WATER AND SEWAGE

PART I—PRIMARY ELEMENTS

By L. D. CARLYON, M.E.
Cleveland, Ohio

In modern sewage plants and water works, metering equipment is now recognized for the important part it plays in obtaining efficient control and operation.

Regardless of type, large meters and registering devices depend upon the so-called "Venturi" principle for their operation. This consists of producing a differential pressure which varies in a definite and known relation to the rate of flow. The differential pressure is mechanically converted into terms of weight or volume and is so indicated and recorded by registering equipment. The actual registers themselves are constructed to provide various combinations of indicating, recording, and totalizing features.

There are three commonly used devices, which can be inserted in fluid lines to produce the desired differential pressure. These are the Venturi tube, the flow nozzle, and the thin plate orifice. Each provides a reduction of the area through which the flow takes place, thereby causing an increase in velocity at this point with a corresponding localized reduction in pressure. The result is a differential in pressure between two areas of the Venturi tube, or on either side of the flow nozzle or orifice inserted in the pipe. Figure 4 illustrates the head differentials created by an orifice insert.

For a given installation the primary element is designed and constructed so that when the maximum rate of flow occurs, a definite maximum head differential will be produced. This varies from a water differential of less than 10 inches to one of more than 200 inches, dependent upon the fluid to be measured, the static pressure, the maximum capacity and the type of register.

Although any one of the three primary elements (Venturi, flow nozzle, or plate orifice) can normally be used, there will usually be one of the three which is best suited to meet the existing requirements. The selection is determined by a number of factors. These factors are to be dealt with in this article, with a view of better acquainting engineers, superintendents or operators with the more important considerations in selection of metering devices. It is hoped that some of the confusion concerning these devices which exists in the minds of some will be cleared away by the following discussion.

Fundamental Comparisons

The Venturi Tube

The Venturi tube has been used for years in connection with projects of the hydraulic and sanitary engineer. As illustrated in Fig. 1, it is designed with a short cylindrical section at the inlet end of the tube, which is cast smooth inside. The high pressure connection is made at this point into the piezometer ring (Fig. 1, Section AA).

*Mechanical Engineer, Bailey Meter Co.

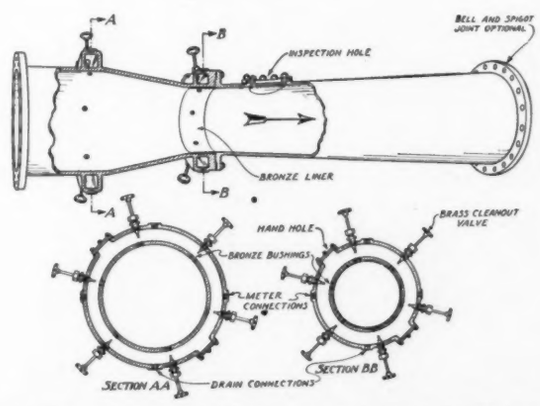


Fig. 1—Venturi Tube. (Handholes and Cleanout Valves Are Used Only for Measurement of Screened Sewage or Sewage Sludges)

Fig. 2—Venturi Throat Section for a 56-Inch Line, Constructed of Cast Iron with a Machined Bronze Liner

Following the inlet section is an entrance cone of about 21 degrees total angle, which leads to the short cylindrical throat section where the low pressure connection to the meter is made through another piezometer ring. At the throat the tube is flanged, and has a handhole which permits inspection of the throat and piezometer holes, as well as accurate measurement of the throat diameter. An exit cone, known as the diffuser, follows the throat and has a total angle of approximately 5 degrees. This ends in a flange for connecting the tube to the pipe line flange.

In certain cases due to objection to the laying length of the long Venturi tube or possibly for reasons of cost, a tube referred to as a "short Venturi" is used. It differs from the long tube primarily in that the angle of the exit cone is much greater (normally 13 to 15 degrees total angle), thus making the overall length much less than a long tube of corresponding diameter which is justified on the grounds that a smaller head loss is created.

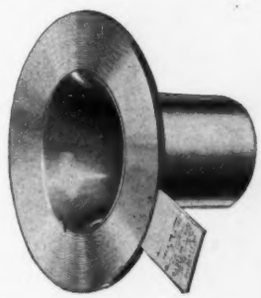


Fig. 3—Flow Nozzle

The majority of Venturi tubes are fabricated of cast iron and are provided with brass or bronze liners in the throat which are machined smooth within close tolerances. Small tubes of from 1 to 2 inches diameter are often made of brass or bronze throughout and the entire length of the internal surface may be completely machined all over. Very large ones have been constructed of concrete or steel plate with a cast iron throat section having a machined bronze liner, such as shown in Fig. 2.

Flow Nozzle

In many respects the flow nozzle (Fig. 3) may be considered to be a simplified Venturi tube. The entrance consists of a gradual curve of approximately one-quarter ellipse which leads the fluid smoothly into a short cylindrical throat section. Thus the discharge jet will have no contraction and will be the same diameter as the throat itself.

Installation of the flow nozzle is made by inserting it between a pair of pipe flanges. The high pressure upstream connection is usually made by tapping the pipe line approximately 1 pipe diameter back of these flanges, and the low pressure connection is made on the line at a point just opposite the throat section of the nozzle. For the measurement of water, air, sewage or

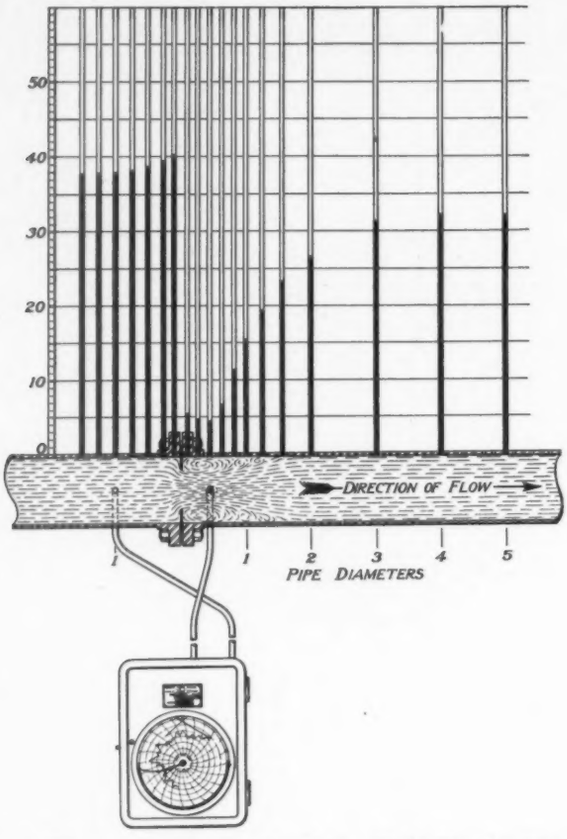


Fig. 4—Diagram of "Stream Lines" in a Fluid Flowing Through a Circular Concentric Orifice in a Pipe, Pressures Existing at Various Distances from the Orifice

sludge, flow nozzles are usually fabricated of bronze, the inside being very accurately machined.

Thin Plate Orifice

The thin plate, or sharp edged orifice, shown in Fig. 4 has been widely used for many years to measure the flow of fluids. In its simplest and most familiar form, the orifice is merely a hole in a flat plate which is clamped between flanges in the pipe line. It may be of 1/16 inch thickness or more, depending upon its diameter, and can be made of nickel, monel metal, steel or other suitable material. Flow meter literature abounds with results of thousands of experiments proving conclusively that the orifice operates on the same basic principles as does the Venturi tube and flow nozzle.

Referring to Fig. 4 it will be noted that there is a well-defined Vena Contracta (plane of greatest contraction) on the down-stream side of the orifice plate, just as is observed when the stream from a sharp edged orifice discharges into the open air. The pressure on the outlet side of the orifice varies along the length of the pipe with the velosity of the stream itself, the observed pressure being least (differential the greatest) when the connection is exactly opposite the Vena Contracta.

The location of the Vena Contracta remains constant regardless of the rate of flow for any one installation. It assumes a slightly different position, however, with different ratios of orifice diameter to inside pipe diameter. For a given ration, its relative position is independent of pipe size. The high pressure upstream tap is made at approximately one pipe diameter back of the orifice, and the low pressure tap is made exactly opposite the Vena Contracta. Some manufacturers recommend that the taps be close to and on either side of the orifice plate; in this case it is necessary to obtain the orifice plate and the flanges as an integral assembly.

Factors to Consider

Before a metering element is specified or selected for a given project, six factors must be taken into consideration if the most suitable arrangement is to be secured; namely (1) initial cost, (2) installation, (3) accuracy, (4) reliability, (5) pressure loss, (6) capacity change.

The above factors may not appear in their order of importance, for the item which is of primary importance for any one application will vary with conditions peculiar to that application.

1. Initial Cost

The initial cost (purchase price) of the primary element may vary within wide limits. Figure 5 illustrates the approximate relationship between present-day prices of long Venturi tubes, short tubes, bronze flow nozzles, and thin plate orifices. It will be noted that for a given size, the price decreases in the order named. Without question the orifice has a decided advantage with respect to initial cost, being approximately one-ninth that of a long Venturi tube of corresponding size.

In the larger sizes, say above 24 inches, it is also possible to obtain orifices at prices from 20 to 25 per cent lower than those shown, by specifying a steel orifice plate having a nickel insert. This insert has the orifice hole machined in it and thus the more expensive metal is used only where it is essential.

Very large Venturi tubes become cumbersome and expensive. On this account large tubes are frequently constructed of steel plate or concrete at its location and only the throat section is purchased from the meter manufacturer.

2. Installation

From the standpoint of ease of installation, the orifice or flow nozzle would be selected in preference to a Venturi tube. They need merely be inserted between a pair of flanges in the pipe line, but considerable care must be taken to center the element properly, to make the pressure connections at the correct locations, and to see that there are no protrusions left on the inside of the pipe line as the result of making the taps.

The Venturi tube being relatively larger and much heavier, more time and labor is required in the installation. If the pipe line is an existing one, it will be necessary to remove one or more sections of pipe and to provide filler pieces of the correct length so that the tube can be made a part of the line. On a new project, however, in comparing the cost of installing a Venturi tube a credit representing the cost of a section of straight pipe of the same length, which otherwise would be required if a flow nozzle or orifice were used, should be considered.

Since the pressure taps are an integral part of the tube, these can be assumed to be correctly placed.

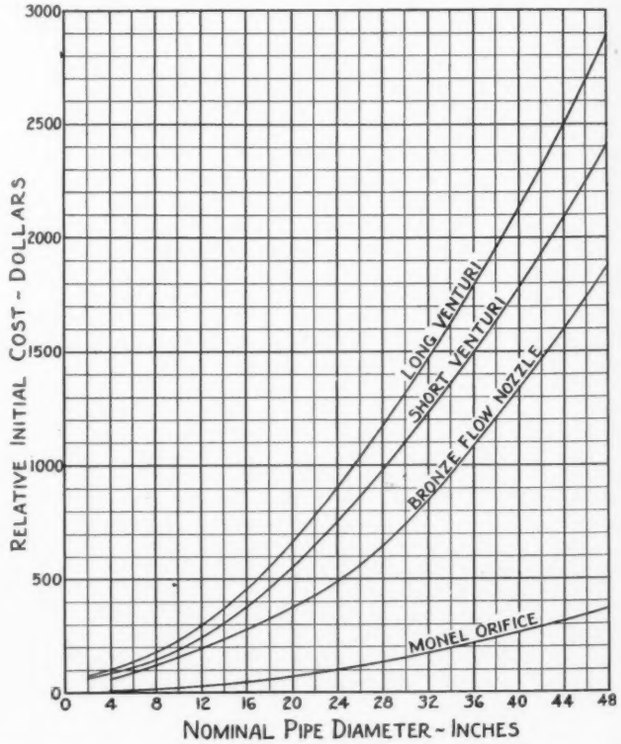


Fig. 5—Curves Showing the Approximate Purchase Prices (at Factory) of Various Types of Primary Elements. (The Curves for the Venturi Tubes Are Based on Weights Suitable for Use with Class A, B, and C Cast-Iron Pipe, and Do Not Include Handholes or Cleanout Valves Shown in Fig. 1)

BAILEY METER COMPANY

1072 Ivanhoe Road, CLEVELAND, OHIO

BOSTON NEW YORK ST. PAUL BUFFALO KANSAS CITY PITTSBURGH HOUSTON ERIE DENVER CINCINNATI SAN FRANCISCO CHICAGO MILWAUKEE

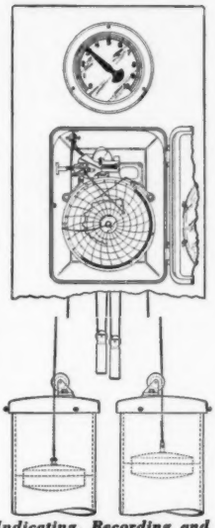
BAILEY METER COMPANY LIMITED, Montreal, Canada

METERS, GAGES and CONTROLLERS for SEWAGE TREATMENT and WATER SUPPLY

STANDARD BAILEY REGISTERS

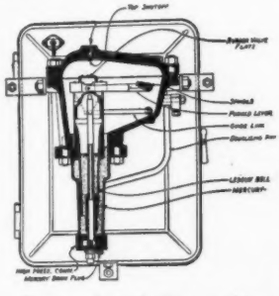
Open Float Tube Type—This register accurately measures the flow of sewage, sludge, dirty water or other liquids, using a Venturi tube, flow nozzle or orifice as the primary element. The external appearance of this indicating, recording and integrating register is shown in the installation photograph below. All parts are of stainless steel, copper, aluminum or other materials especially selected because of their ability to withstand the corrosive action of sewage, gas and sludge.

A high degree of accuracy is insured by a large float and a relatively large float motion applied through differential gearing and a cam to operate the register in direct proportion to the rate of flow. *Ask for Bulletin No.* 39.



Indicating, Recording and Integrating open float tube type Register.

Ledoux Bell Type—This register, operated by a mercury sealed Ledoux Bell is particularly well adapted to the measurement of sewage, sludge or water under pressure or where wide changes in hydraulic gradient are encountered. When applied to the measurement of sewage or sludge, settling chambers are used and a supply of fresh water is introduced so that a constant flow exists from the register to the Venturi tube. This is, of course, unnecessary when the meter is applied to clean water measurement.

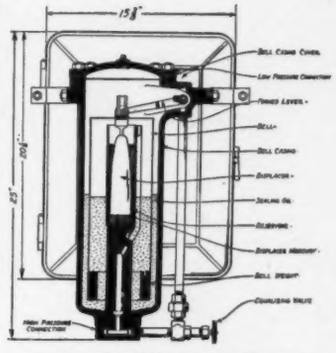


Section through flow mechanism of Ledoux Bell type Register.

In the water works field this register is particularly well adapted for use on discharge lines from centrifugal pumps, on gravity mains, on branch lines in distribution systems, and in filtration plants to measure raw water, clear water and wash water.

Suitable equipment can be furnished when it is desired to totalize the flow through several lines. *Write for Bulletin No.* 301.

Air Meters—These meters measure air flow in main lines and in individual lines to aeration tanks. It is desirable to meter both air and sewage to individual aeration tanks in order that they may be properly proportioned for best results in consideration of such factors as quality of raw sewage, detention, tank agitation and economical use of air.



Section through flow mechanism of Air Meter

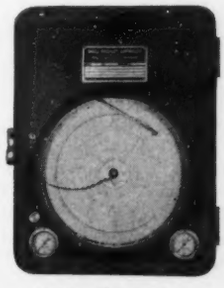
This register differs from the Ledoux Bell type, previously described, only in the flow mechanism which in this case is designed to operate on a maximum differential of 8" of water. The motion of the oil sealed bell is transferred to the uniformly graduated chart by means of a forked lever, spindle and recording pen. *Described in Bulletin No.* 39.

Remote Registers—Bailey Telemetering systems make it possible to operate remote indicating, recording or integrating registers, which may be installed at a distance from the direct connected unit. These registers may measure flow in individual lines, total flow, liquid level, pressure and other factors.

Venturi Tubes—Standard Bailey Designs include a complete range of Venturi tubes and other primary elements suited to the measurement of sewage, sludge and water. The selection of a suitable primary element is governed by such factors as capacity required, type of flanges, pressure loss allowable and character of fluid to be metered.

Controllers—Bailey Controllers utilize standard Bailey Meters and Recorders as the basic measurement source for the automatic control of factors, such as flow, ratio, pressure and liquid level. They are operated by compressed air at approximately 35 lbs. pressure and match perfectly with other Bailey gages and registers.

Bailey control is fully automatic, dependable and exceptionally flexible. *Ask for Bulletin No.* 101.



Bailey Recorder—Controller.

Bailey Registers measuring Sewage, Sludge and Air in an operating gallery at Easterly Sewage Treatment Works, Cleveland, Ohio.

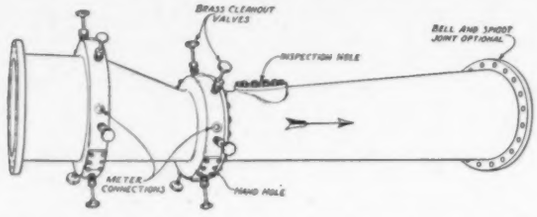


Fig. 6—Eccentric Type Venturi Tube for Sewage or Sewage Sludges

3. Accuracy

When installed under suitable conditions, the three primary elements are very nearly equal when compared on the basis of accuracy obtainable; namely, within 1 per cent of 100—plus or minus. Due to small inaccuracies introduced by the register mechanism, however, manufacturers normally extend a conservative guarantee that the reading will be within 2 per cent of 100 plus or minus. In actual practice the accuracy always falls well within the limits of the guarantee.

In order to insure accurate metering, all primary elements require a certain length of straight pipe preceding the location. For the Venturi tube, 5 to 10 pipe diameters are usually adequate. For the flow nozzle or orifice types this requirement is between 8 and 20 pipe diameters, depending on the ratio of orifice diameter to inside pipe diameter, and on the piping layout. Sometimes these requirements cannot be met due to the piping layout. It is under such conditions that the short Venturi tube occasionally proves most suitable because it is from 30 to 45 per cent shorter than the long tube of like diameter.

In order to preclude high readings on the registering device, the primary element should not be installed where the air or liquid flow is of a rapidly pulsating nature. Such a condition may be caused by water or sewage reciprocating pumps and by certain types of air blowers. It is sometimes possible to eliminate pulsations or dampen them materially but where pulsating flow is likely to be a problem this factor should be called to the meter manufacturers' attention; whereupon, specific recommendations will be made.

4. Reliability

It is essential that the primary element retain its accuracy after installation and that it also provide continuity of satisfactory service.

Screened sewages and sewage sludges present the greatest problem of measurement because of solid matter or gas which they contain. For this service the piezometer rings of the Venturi tube are equipped with cleanout valves (Fig. 1) which facilitate routine cleaning operations to maintain the openings free from obstructions. Connections should be made at top and bottom of each ring for venting accumulating gas or draining sediment. Handholes in each ring make the interior accessible.

At low velocities the throat section of the Venturi tube may act as a dam causing foreign material to settle on the bottom of the inlet cone and, thereby, affecting the accuracy. A condition of this kind can be largely avoided by the use of an eccentric Venturi tube (Fig. 6) which differs from the ordinary tube only in the eccentric shape of the converging and the exit cones. The fact that the bottom of the tube lies in one horizontal plane makes it easier for solid materials to be swept through the tube.

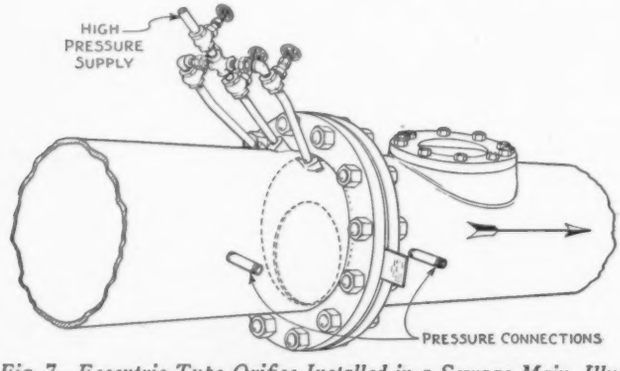


Fig. 7—Eccentric Type Orifice Installed in a Sewage Main, Illustrating an Arrangement for Washing Collected Materials Off the Face of the Orifice Plate

An installation of an orifice in a sewage line is illustrated in Fig. 7. Here also the eccentric type is of particular advantage in that solid materials pass through without obstruction. While there is even less chance of materials settling on the sharp edged opening than in the throat of a Venturi tube, there is a greater possibility of material collecting on the entrance side of the plate. For this reason it is desirable to provide a high pressure water supply into the pipe line (Fig. 7), for periodically washing off the face of the plate.

A common method for the prevention of plugged taps, and to keep the meter connections clean and free of deposits is to introduce a continuous trickle of clean water through the connecting pressure lines to create a slow current into the main pipe line.

Unless there is some especial factor involved, the flow nozzle should be avoided in metering sewage, because there is a tendency for materials to deposit in the throat section and to build up at the entrance. However, it has proved satisfactory where a

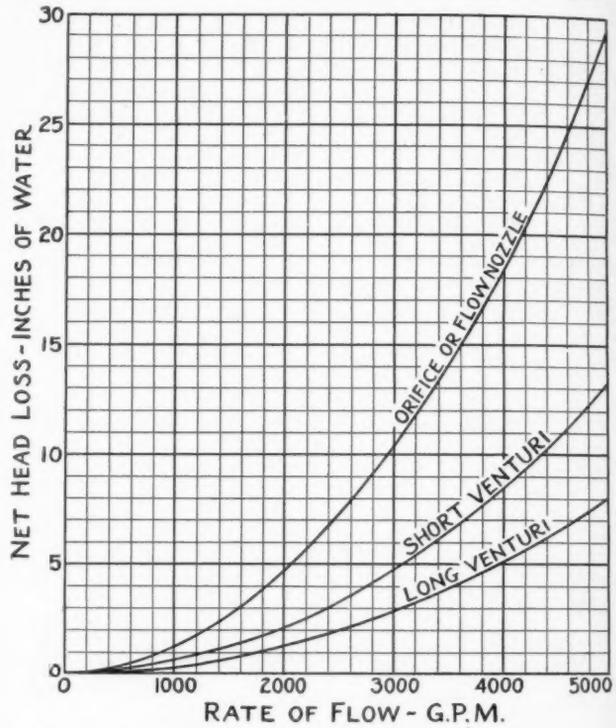


Fig. 8—Curves Showing the Net Differential Head Loss Created by Different Types of Primary Elements, Designed for a Maximum Differential of 53 Inches of Water, at a Maximum Capacity of 5,000 g.p.m., as Applied to a 20-Inch Water Main

means has been provided for flushing out the entrance and throat frequently.

Measurement of unscreened sewage should be avoided, except where there is no alternative, as for example when one community has its sewage treated in the plant of another municipality. The large heavy solids may cause greater wear and erosion on the primary element, and in the case of an orifice installation, there is the added danger of an object striking the plate with sufficient force to cause distortion.

Comparatively little attention is required for primary elements in air lines or fresh water mains, and all three elements will function indefinitely with practically no attention.

5. Pressure Loss

The differential head created by any of the three primary elements represents only a localized drop in pressure, most of which is restored upon resumption of normal flow a short distance following the primary element as is pictured in Fig. 4. It is important to hold head losses to a minimum, especially when capacities are large and available head is at a premium, or where pumping is involved and power requirements must be considered.

With the long Venturi tube, the pressure loss at any rate of flow is only approximately 15 per cent of the actual differential head produced by the element at that rate of flow, whereas with the short tube the loss is approximately 25 per cent.

The percentage loss created by orifices or flow nozzles depends

(*Continued on page 372*)

BUILDERS IRON FOUNDRY

9 Codding St., Providence, R. I.

New York: 20 Vesey St. Philadelphia: Tax Service Bldg. Chicago: 866 Peoples Gas Bldg. Pittsburgh: 1403 Oliver Bldg.

REPRESENTATIVES

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CLEVELAND, OHIO, Maxfield Pease, 4614 Prospect Ave.
DALLAS, TEX., Morey & Morey, 417 Praetorian Bldg.
DENVER, COLO., J. B. Ambler, P. O. Box 591.
DETROIT, MICH., William A. DaLee, Inc., 4829 Woodward Ave.
KANSAS CITY, MO., G. C. Kahl, Dwight Bldg.
LOS ANGELES, CAL., C. P. Crowley, 609 South Anderson St.
OMAHA, NEB., Pasol Engineering Co., P. O. Box 697.
ST. LOUIS, MO., Power Equipment Co., 4903 Delmar Blvd.
ST. PAUL, MINN., Commonwealth Electric Co., 417 Broadway.
SALT LAKE CITY, UTAH, Riter Engineering Co., 314 Kearns Bldg.
SAN FRANCISCO, CAL., Strout-Steffens Equipment Co., 357 Ninth St.
MONTREAL, P. Q., CAN., Drummond, McCall & Co., Ltd., Box 219.
TORONTO, ONT., CAN., Control & Metering, 454 King St. W.
MEXICO, D. F., MEXICO, J. M. Chavez, Isabel la Catolica 14.
BUENOS AIRES, ARGENTINA, Fiore Company, Avda, Roque Saens Pena, 832.
BOGOTA, COLOMBIA, Lobo Guerrero & C. S. de Santamaria Edificio Santa Fe, No. 207.

PRODUCTS

Venturi Meters for Water, Sewage, Sludge, and Air; Orifice Meters for relatively less important lines; Venturi Rate of Flow Controllers; Loss of Head and Rate of Flow Gauges; Reservoir and Tank Elevation Gauges; Sewage, Sludge, and Air Flow and Ratio Gauges. Chronoflo Meters for Distant Metering, Summation of Meter Totals, Continuous Sludge Weighing, Chemical Feeding, Suction Well Level and Pump Control. %Proportioneers% Devices for Water and Sewage Treating and Chemical Feeding.

VENTURI METERS—for Water Works and Sewage Plants

Fig. 1. The Venturi Tube

The Venturi Meter is recognized as the standard means of measuring the flow of water in large mains. It consists of the Venturi Tube (illustrated), installed as a section of the main, and the Register-Indicator-Recorder connected to the Tube by two small pressure pipes. From the inlet to the throat of the Venturi Tube the interior diameter gradually decreases and then gradually increases again to the full diameter at the outlet. This design produces a high differential between inlet and throat with minimum overall friction loss. Annular pressure chambers are provided at inlet and throat. Throat is bronze-lined.

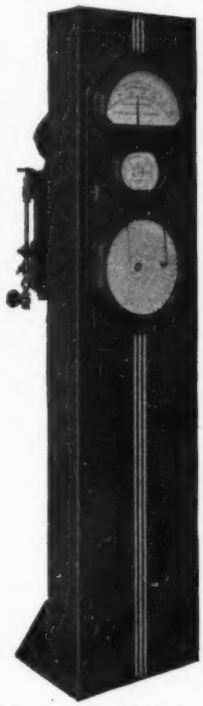

Fig. 2. Type M Register-Indicator-Recorder (Model D)

Several different types of indicating and recording instruments are available for use with the Venturi Tube ranging from the Barometric Type Mercury Manometer to the popular Type M Register-Indicator-Recorder, illustrated. This Register has the advantage of unusual ruggedness and extreme accuracy. The Type M furnishes three distinct kinds of information; an indication of the momentary flow through the Venturi Tube; a permanent record of this rate upon a large circular chart; the total quantity on a circular counter dial. Each Type M is graduated for the particular Venturi Tube with which it is to be used.

VENTURI RATE OF FLOW CONTROLLER

Fig. 3. Direct-Acting Controller

Efficient filtration requires a constant rate of flow through the filter bed. This is automatically accomplished by the Venturi Rate of Flow Controller, installed in the effluent line, which gradually opens as the sand friction builds up and the effluent rate tends to drop. The Venturi Tube Controller, providing the highly desirable combination of accurate control and small loss of head, is "standard equipment."

BUILDERS WATER WORKS GAUGES

Fig. 4. Indicator and Recording Gauge

Loss of Head (through filter) and Rate of Flow (Filter Effluent) Gauges are usually mounted on each filter operating table. Indicating and Recording Water Level Gauges are also furnished.

CHRONOFLO METERS AND THEIR USES

Distant Flow Metering

Chronoflo Meters have found a broad application in bringing to a central operating point, from widely scattered locations, accurate records of flow, level, pressure, temperature, gate position, and weight. Chronoflo Transmitters are electrically connected by a simple two-wire circuit to Chronoflo Indicating and Recording Instruments. (Fig. 5).

Fig. 5. Chronoflo Register-Recorder

Reservoir and Tank Elevation Gauges

in the pumping station and the water works office downtown, continuously indicate and record level in outlying reservoirs, tanks, or standpipes; eliminate the necessity of taking such measurements manually; and promote efficient pumping.

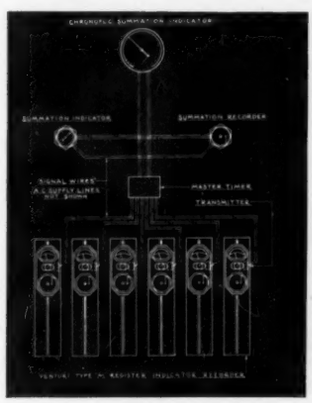

Fig. 6. Totalizing Readings of Six Venturi Meters

Distant Transmission and Summation

The Chronoflo Meter is peculiarly suitable for adding the totals of various individual meters installed in widely separated locations. (Fig. 6).

Continuous Sludge Weighing

In many sewage plants one measure of efficiency of operation is the weight of filter cake carried from rotary filters to final disposal. A recent development is the attachment of a special Chronoflo Weight Transmitter to a Toledo Automatic Scale (Fig. 7), which integrates on a counter the total pounds and records on a continuous chart the rate in pounds per hour.

Fig. 7. Chronoflo Transmitter on Scale

Raw Sewage Suction Well Level and Pump Control

Builders Iron Foundry Engineers are in a position to work with sewage plant designers in providing Venturi and Chronoflo control devices for this service.

ENGINEERING SERVICE

Inquiries for recommendations covering the adaptation of standard metering and controlling devices are invited. Printed bulletins, illustrating and describing devices mentioned briefly in these pages, are available upon request.

upon the ratio of the throat diameter to the internal pipe diameter—the smaller the throat or orifice the greater the percentage loss. When designed for identical conditions of capacity, etc., the percentage loss will be virtually the same for both the orifice and the flow nozzle.

As a typical example, assume that a water meter operating on a maximum differential head of 53 inches of water is to be applied to a 20-inch main and to have a maximum capacity of 5,000 g.p.m. The loss of head created at maximum flow by the various elements as shown by the curve in Fig. 8 would be:

Long Venturi, 7.95 in. water (.15 × 53).

Short Venturi, 13.25 in. water (.25 × 53).

Orifice or Flow Nozzle, 29.15 in. water (.55 × 53).

With a flow of 2,500 gallons per minute (½ of maximum) the losses produced would be only ¼ of these values, because the differential head varies proportionately to the square of the rate of flow.

Although the curves of Fig. 8 apply only to the specific example, it can readily be seen that conditions exist where, by use of a Venturi tube, the reduced cost of pumping over a short period of time will more than offset the higher initial cost of the Venturi tube.

5. Capacity Change

An existing meter installation may at some time require an increase in maximum capacity to meet the requirements of increasing quantities of fluid handled by the system. This may be accomplished in three ways—either by providing a new primary element, by modifying the old one to handle the larger capacity, or by increasing to the required extent the maximum differential head with which the register functions.

With the Venturi tube, the first two methods are costly, particularly in the larger size and therefore the register differential is usually increased. It should be borne in mind, however, that with this method, at rates of flow exceeding the original maximum capacity the pressure loss increases as the square of the flow.

When an orifice or flow nozzle constitutes the primary element, a new one can usually be installed at reasonable cost. Since such a change necessitates a larger orifice the pressure loss will be lower than for the original installation, notwithstanding the increased flows handled. This naturally cannot be accomplished in cases where the primary element originally installed is already near the greatest ratio for which it can be designed. It is necessary then to increase the differential head of the register and suffer the head loss entailed or else to provide a duplicate installation on a parallel twin line.

Knowledge of the principles described and intelligent consideration of the six factors outlined above will aid materially in obtaining primary elements which are most suitable for the particular project from the standpoint of both satisfactory operation and cost.

Final decisions can be made only when complete details and figures are available pertinent to the specific problems under consideration. Therefore, it is important to supply meter manufacturers with as complete data as possible concerning each contemplated meter installation, such as the type of fluid, maximum capacity, pipe diameter, pressure, and a dimensioned sketch of the piping layout.

Part II—Secondary Elements

The secondary element of large meters (more commonly known as a register) is actuated by the differential pressure and, through mechanical or electrical means, converts such into records or indications of the rate of flow. In addition a totalization of the weight or volume passing through the line is registered.

Although there are many types and makes of registers, they depend upon only a few basically different types of mechanisms designed to utilize the differential head. These form the basis for much of the following discussion concerning secondary elements as applied to various services.

Because of the extensive use of the Venturi tube as a primary element, it is desirable to have the register designed so that its capacity can be changed by increasing the maximum differential head upon which it functions without altering the primary element or connecting lines, thereby eliminating expensive replacement of tubes.

Registers may be divided into two general classes of differential translating mechanisms; (1) the open float tube type, and (2) the pressure chamber type.

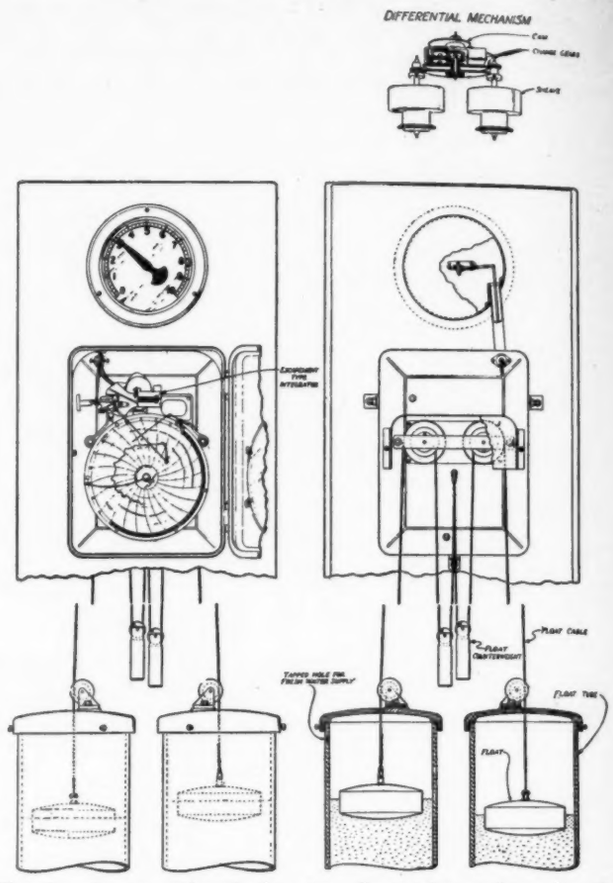

Fig. 1.—An example of the open float tube register for the measurement of sewage, sludge, and dirty water. (Courtesy of Bailey Meter Co.)

The Open Float Tube Register

The open float tube register is used only where the hydraulic gradient is relatively low and where changes in it are not severe. It is most extrensively used in metering sewages and sludge.

One example of the open float operated register is shown in Fig. 1 and a diagrammatic installation of this register, Fig 2, illustrates its position relative to the float tubes, and the Venturi tube.

One float tube is connected to the inlet and the other to the throat of the Venturi tube by pressure piping so that the water level in each tube will rise to a height corresponding to the pressure existing in the Venturi tube at the point where the connection is made.

The rate of flow, represented by the difference in levels of the floats in the float tubes, is transmitted to the register by cables which are attached to sheaves as shown in Fig. 1. These cables operate the differential mechanism and square root cam which in turn transmit the rate of flow to the recording pen, the integrator and the indicator. A square root cam is employed to translate the differential into terms of flow so that the pen motion will be directly proportional to the rate of flow.

Another function of the differential gearing system is to automatically compensate for variations in line pressure or hydraulic gradient. This mechanism is designed so that if both floats rise or fall an equal amount there will be no change in the position of the operating cam. However, if there is a change in the difference between the levels in the float tubes, this change immediately operates the square root cam which in turn moves the recording pen to a new position, thereby registering the variation in rate of flow.

The maximum capacity of this float operated register can be altered by simply changing two sets of gears in the differential mechanism. This feature is provided to eliminate excessive costs for the replacement of the Venturi tube with modern equipment; wide variations in capacity can be obtained without removing the primary element from the line or disconnecting the meter in any way.

The register itself is mounted on the operating floor immediately

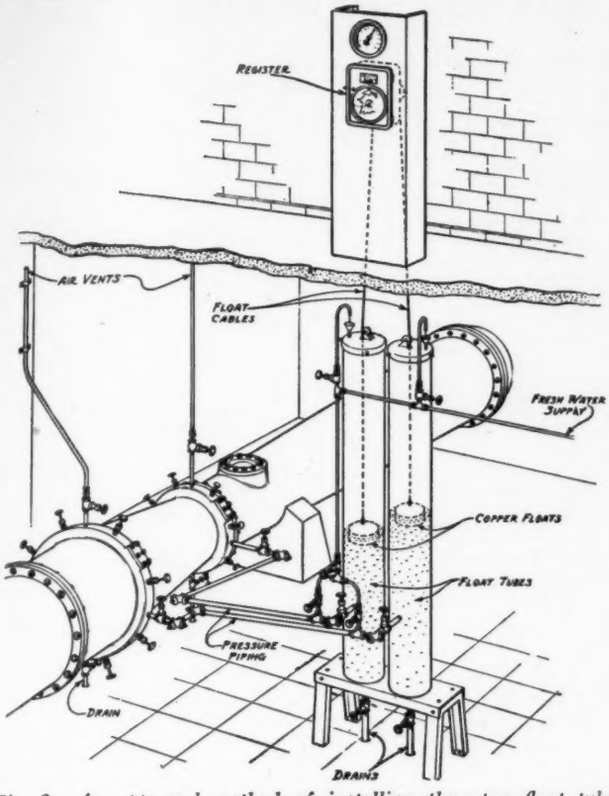

Fig. 2.—An approved method of installing the open float tube register for the measurement of sewage or sludge. (Courtesy of Bailey Meter Co.)

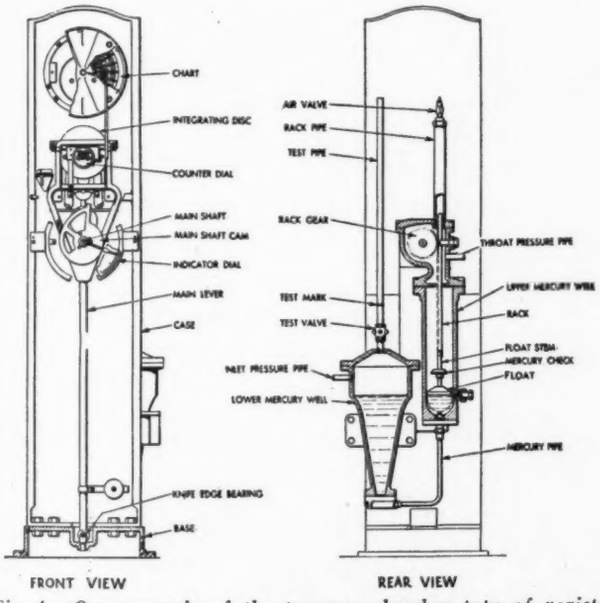

Fig. 4.—One example of the pressure chamber type of register using a float. (Courtesy of Builders Iron Foundry.)

above the float tubes. Cables are strung from the sheaves to the copper floats in the float tubes. This cable system is counterweighted as shown in Figure 1 so that there is an even tension on the float cables at all times. The float tube covers are provided with small pulleys to guide the copper floats in the center of the tubes without undue friction in the mechanism.

A satisfactory method of installing the float operated register is represented by Fig. 2. The float tubes are usually made of 10-inch cast iron pipe and should be located directly below the register and as close to the Venturi tube as conditions will permit. A constant supply of fresh water is slowly introduced into the float tubes so that the water flows from the tubes out through

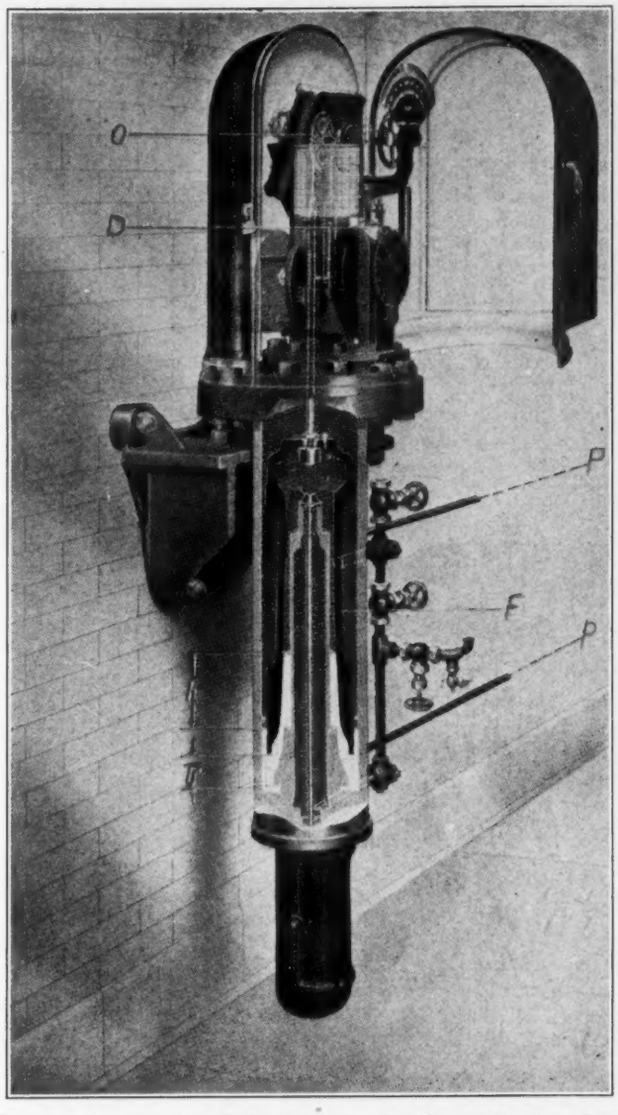

Fig. 3.—An example of the pressure chamber type of register using a mercury sealed bell. (Courtesy of Simplex Valve and Meter Co.)

the pressure piping to the Venturi tube thereby minimizing the accumulation of solid matter in the system. Provision is also made for flushing out the pressure piping with clean water under pressure, and also for cleaning the inside surface with a brush or "ram" should such be necessary. The float tubes are fitted with shut-off valves and drain connections.

The piping connecting the Venturi tube with the float tubes is sloped (grade of ½-inch or more per foot) to prevent air or gas from becoming trapped in the piping and causing false levels to exist in the float tubes. The piping should be of 1-inch or larger copper or red brass pipe joined together with crosses at all changes of direction so that it may be rammed or brushed clean by removing the pipe plugs from each end of the run to be cleaned. Gate valves should be used on these lines instead of globe valves because they open to provide a free and unrestricted passage through the pressure piping, which is necessary to facilitate cleaning.

The fresh water supply piping may be readily constructed of copper tubing and compression fittings. Copper tubing of ½ inch diameter usually furnishes sufficient fresh water for the sight feeds.

Vents, leading to a point above the maximum hydraulic gradient, should be provided at the inlet and throat rings of the Venturi tube as shown in Fig. 2. To insure continuous venting, these vents should be left open at all times except when flushing the piezometer rings.

The "standard" arrangement of register and float tubes (Fig.

(*Continued on page 376*)

SIMPLEX VALVE & METER COMPANY

68th and Upland Streets, Philadelphia

SIMPLEX REPRENTATIVES

DETROIT, MICH., DuBois Company, F. W. DuBois, President, 2832 East Grand Blvd.

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MILWAUKEE, WIS., Fred H. Dorner, 1107 East Knapp Street or P. O. Box 1000.

MINNEAPOLIS, MINN., Kent-Ervin Engineering Co., 732 Builders Exchange Building.

ATLANTA, GA., W. D. Taulman, 179 Spring St., S. W.

ROCHESTER, N. Y., A. W. Schuster, 1023 Granite Building.

DENVER, COLO., Denver Fire Clay Co., 2301 Blake Street.

SALT LAKE CITY, UTAH, Denver Fire Clay Co., 157 W. Second South St.

SALT LAKE CITY, UTAH, C. E. Painter, % Waterworks Equipment Co., 149 West Second South Street.

EL PASO, TEX., LeRoy G. Hetrick, Denver Fire Clay Co., 209 Mills Building.

NEW YORK CITY, N. Y., W. K. Sowdon Company, 342 Madison Avenue.

LOUISVILLE, KEN., R. M. Overstreet, 1441 South 4th Street.

CLEVELAND, OHIO, A. MacLachlan, 1740 East 12th Street.

LOS ANGELES, CALIF., R. W. Lawton, 1115 South Hope Street.

OMAHA, NEB., O. F. Barklage & Co., Hotel Keen, 18th and Harney Sts.

SAN FRANCISCO, CALIF., Water Works Supply Company, 501 Howard St.

TULSA, OKLA., McGregor & Thilenius, Suite 208 Midco Building.

NEW ORLEANS, LA., A. C. Hays, 1415 Carondelet Building.

SEATTLE, WASH., H. D. Fowler, 419 Smith Tower.

BOSTON, MASS., Hayes Pump & Machinery Co., 125 Purchase St.

DALLAS, TEX., L. E. Livingston, 3921 Purdue St.

CHARLOTTE, N. C., T. C. Heyward, Independence Building.

PITTSBURGH, PA., Ross Mechanical Supply Co., 435 Water Street.

CANADA, Simplex Valve & Meter Company of Canada, Ltd., S. A. McWilliams, 60 Front Street, West, Toronto, Ont., Canada.

CUBA, Daniel, Inc., Metropolitan Building 814, Habana.

HAWAII, W. A. Ramsay, Ltd., Fort and Queen Sts., Honolulu.

MEXICO, F. A. Zapata, Apartado Postal No. 99, Mexico, D. F., Mexico.

PUERTO RICO, Roberto Colon Machinery Manufacturing Co., Comercio Street 17-19, San Juan.

PRODUCTS:

Simplex Venturi Type Meters for Measurement of Water, Sewage, Sewage-Sludge, and Air; Filter Rate of Flow Controllers; Loss of Head and Rate of Flo Gauges; Simplex Pump Casing Tap Meters; Pilot Tubes and Manometers; Portable Pitot Recorders; Water Level Gauges; Air Release and Air and Vacuum Valves; Proportional Chemical Feeding Devices; Sewage Aerators; Rotary Distributors; Hydraulic Equipment of Special Design; Sand Expansion Indicators.

SIMPLEX METER REGISTERS:

Primarily designed for use with Venturi tubes, Simplex meter registers are also used with Simplex pitot rods, orifice plates, and pump casing taps, as primary actuating devices. They are designed for use in measuring liquors and gases under all pressure conditions and are particularly fitted for the measurement of raw water, wash water, filtered water, raw sewage, screened sewage, mixed liquor, raw sludge, digested sludge, and air.

Noted for their ability to operate under small Venturi heads, Simplex meter registers measure accurately flows corresponding to water differentials of from ⅛" and up. Particularly designed to measure accurately the slightest change in rate of discharge, Simplex meters can be furnished to either indicate, record, or totalize the flow, or in any combination of these functions. Simplex meter registers of standard form are also furnished for the measurement of discharge through egg-shaped flumes, Parschall Venturi flumes, weirs, and other forms of primary devices wherein a free-falling discharge is present as well as for use with Simplex Pump Casing Taps.

Simplex meter registers can be arranged for mechanical totalization of the flow from any number of individual instruments whereby the total flow can be transmitted to either a large dial indicator, a total flow recorder, or a complete summation meter of the indicating, recording, and totalizing type.

Simplex meter registers can be operated by air differentials, thereby preventing the entrance of any sewage, sludge, or corrosive liquors into the meter float cylinder.

Each instrument has included with it as a standard item of equipment a device whereby its accuracy and sensitivity can be checked at any time during its period of service.

SIMPLEX FILTER RATE OF FLOW CONTROLLERS:

Provide an efficient device for the operation of gravity or pressure filters which maintain the rate of discharge through the bed at a constant, regardless of variations in pressure or water level, utilizing as an operating means only the pressure effect of the water flowing through the filter effluent line.

Simplex Controllers operate with the lowest obtainable head losses when wide open; attain the highest degree of accuracy in control without the use of compensating mechanisms; and are capable of covering the largest possible ratio from maximum to minimum rates with any given size of unit; avoid the use of any

electrical mechanisms in their operation; start quickly from a wide open position, and take the rate for which set in less than fifteen seconds.

The Simplex, direct-acting controller is arranged for either straight-through, right, or left-hand outlet as may be desired, and can be installed in either a vertical or horizontal line, as required.

Simplex rate of flow controllers can be equipped with the Simplex master control system, whereby the rate through the entire battery of filter units can be changed from a single point on the operating floor or wherein the rate through each controller unit will vary with the elevation of water on the filter or in the clearwell.

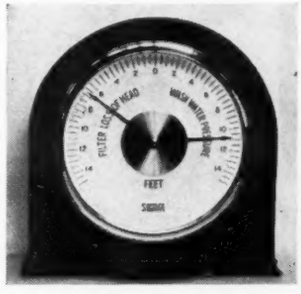
Simplex rate controllers can also be arranged with means for changing the rate from the operating floor.

SIMPLEX FILTER GAUGES:

These may be furnished in any combinations of indicating, recording, and totalizing rate of flow with indicating and recording of lost head, wash water rate or sand expansion.

Simplex gauges are of the mercury float operated type, wherein the Simplex bell-shaped float is used to provide uniform graduations of flow on both indicating dial and recording chart.

Similar in design to the Simplex meter register, Simplex filter gauges respond to the slightest variations in rate or loss, and will measure accurately over the entire range with an average error not exceeding ± 3%.



Simplex rate of flow gauges have been arranged for totalization, wherein there is shown on a single 24" diameter dial gauge, located on the operating floor, the total flow through any or all of the controller units. There can be mechanically linked to the total flow indicator, chemical feeders or chlorinators, thereby providing accurate control of the chemical dosage at all time during the plant run.

Simplex Sand Expansion Indicators and Recorders provide a means whereby filter efficiency can be increased and wash water costs reduced. They are available for installation on existing filter units as well as on new plants.

Also available for measuring the depth of water in clear wells, wash water tanks, sedimentation basins, are Simplex water float operated gauges, which can also be furnished in any combination of the indicating and recording types.

Simplex gauges are accurate, dependable, and easily intsalled—a high-grade quality product, made with precision and care.

SIMPLEX AIR RELEASE AND AIR AND VACUUM VALVES:

In the design and operation of large steel pipe lines flowing under gravity, consideration should be given to the possibility of collapse, in case, for any reason, the internal pressure is reduced below that of atmosphere.

Simplex Air and Vacuum Valves are used on large mains, where there is danger of collapse, due to vacuum; the valve breaking the vacuum, thus preventing collapse. They facilitate the filling of the main, since wide open until full of water.

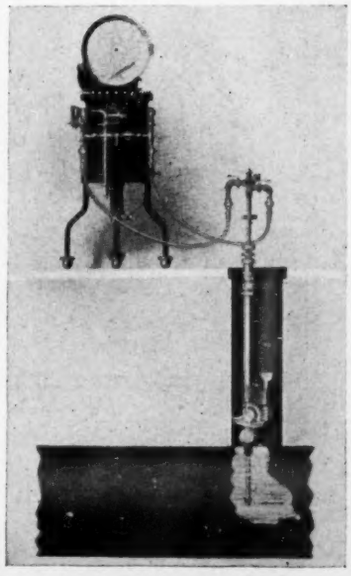
Simplex Automatic Air Release Valves have been designed to release, automatically, accumulations of air. They possess the merits of continuous operation without attention; simplicity; compactness; accessibility, and low cost, all of which are proved by over fifteen years' satisfaction to many users. Located on the high portions of the line, they insure automatic venting of the line and a continuous flow.

SIMPLEX TUBE RECORDERS:

For use with Simplex Round or Flat Pitot Rods —afford not only a record of velocity but can be furnished with pressure elements to give simultaneous readings of velocity and pressure.

This equipment may also be used for Water Waste Surveys or for conducting water flow investigations.

Indispensable to water works engineers for determining character of the flow in the mains of the distribution system.



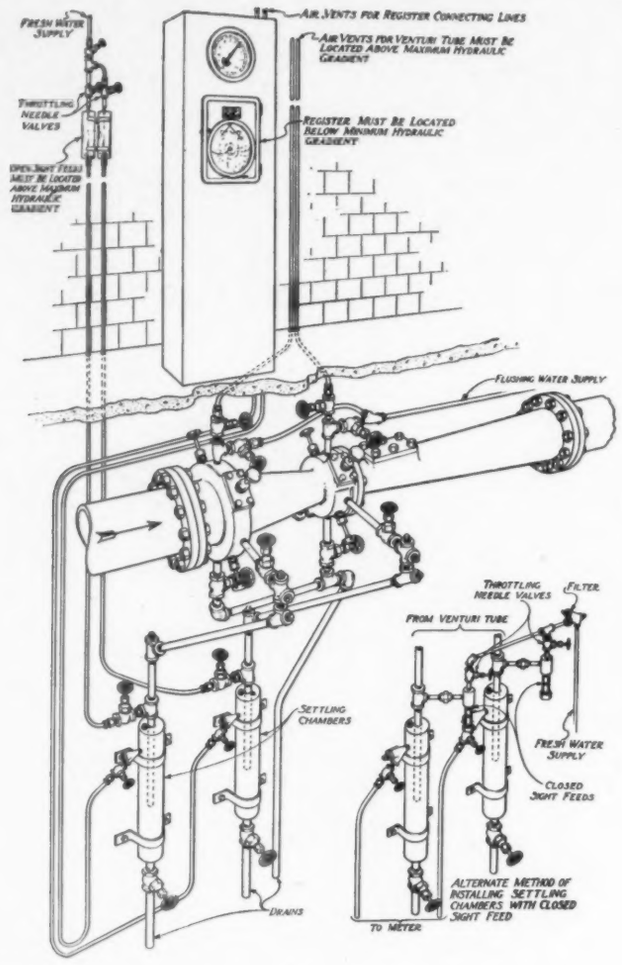

AIR VENTS FOR REGISTER CONNECTING LINES
AIR VENTS FOR VENTURI TUBE MUST BE LOCATED ABOVE MAXIMUM HYDRAULIC GRADIENT
REGISTER MUST BE LOCATED BELOW MINIMUM HYDRAULIC GRADIENT
FRESH WATER SUPPLY
THROTTLING NEEDLE VALVES
OPEN SIGHT FEEDS MUST BE LOCATED ABOVE MAXIMUM HYDRAULIC GRADIENT
FLUSHING WATER SUPPLY
THROTTLING NEEDLE VALVES
FILTER
FROM VENTURI TUBE
SETTLING CHAMBERS
FRESH WATER SUPPLY
CLOSED SIGHT FEEDS
ALTERNATE METHOD OF INSTALLING SETTLING CHAMBERS WITH CLOSED SIGHT FEED
DRAINS
TO METER

Fig. 5.—A recommended method of installing the pressure chamber register, whether bell or float type, for the measurement of sewage or sludge. (Courtesy of Bailey Meter Co.)

2) is not satisfactory in cases where the maximum hydraulic gradient rises above the register location. For installation under such conditions, the register may be mounted at an elevation *below* the float tubes and motion of the floats can be transferred to it by running the cables over a suitable arrangement of pulleys. Conditions of this kind can also be satisfactorily handled by the pressure chamber type of register and the sight feed system described in the following section.

Pressure Chamber Register

Where line pressures are high, or when wide changes in the hydraulic gradient are to be encountered, the pressure chamber operated register should be used. With this type of meter, the pressure piping from the primary element is connected directly to the flow mechanism of the register which contains either a bell or a float.

One example of a pressure chamber register using a bell is shown in Fig. 3. The actuating mechanism, a hollow float of bell shape which is sealed in mercury, is subjected on the outside to the higher pressure from the approach side of the primary element and on the inside to the lower pressure. The float is shaped so that the resultant downward movement, from its position at zero differential head to the position of equilibrium, is directly proportional to the instantaneous rate of flow through the primary element.

Movement of the float is transmitted to a sheave, usually by a flexible cable provided with a counterweight and sheave clamp. The sheave is fixed to a shaft carried on pivot bearings. After passing through the stuffing box, the shaft further supports the flow pointer, the recording pen, and the integrating mechanism.

An example of the float type of pressure chamber register is illustrated in Fig. 4. The pressure connections from the primary element are connected to the two sides of a mercury U-tube, the higher pressure being connected to the tapered well, and the lower pressure to the well containing the float. As the rate of flow varies through the primary element, the mercury level in the U-tube will also vary, thus raising or lowering the float. This motion, through the rack and gear, provides the motive power for operating the indicating, recording, and integrating mechanisms.

The specially tapered well of the U-tube partially extracts the square root of the differential, and the remainder of the function is converted by a shaped cam in the register so designed that actual motion of the recording pen and indicator becomes directly proportional to the rate of flow.

One method of installing the pressure chamber type of register in accordance with good engineering practice is represented by Fig. 5. Foreign matter is prevented from entering the register flow mechanism and connecting piping by the open sight feeds and the settling chambers. The sight feeds cause fresh water to

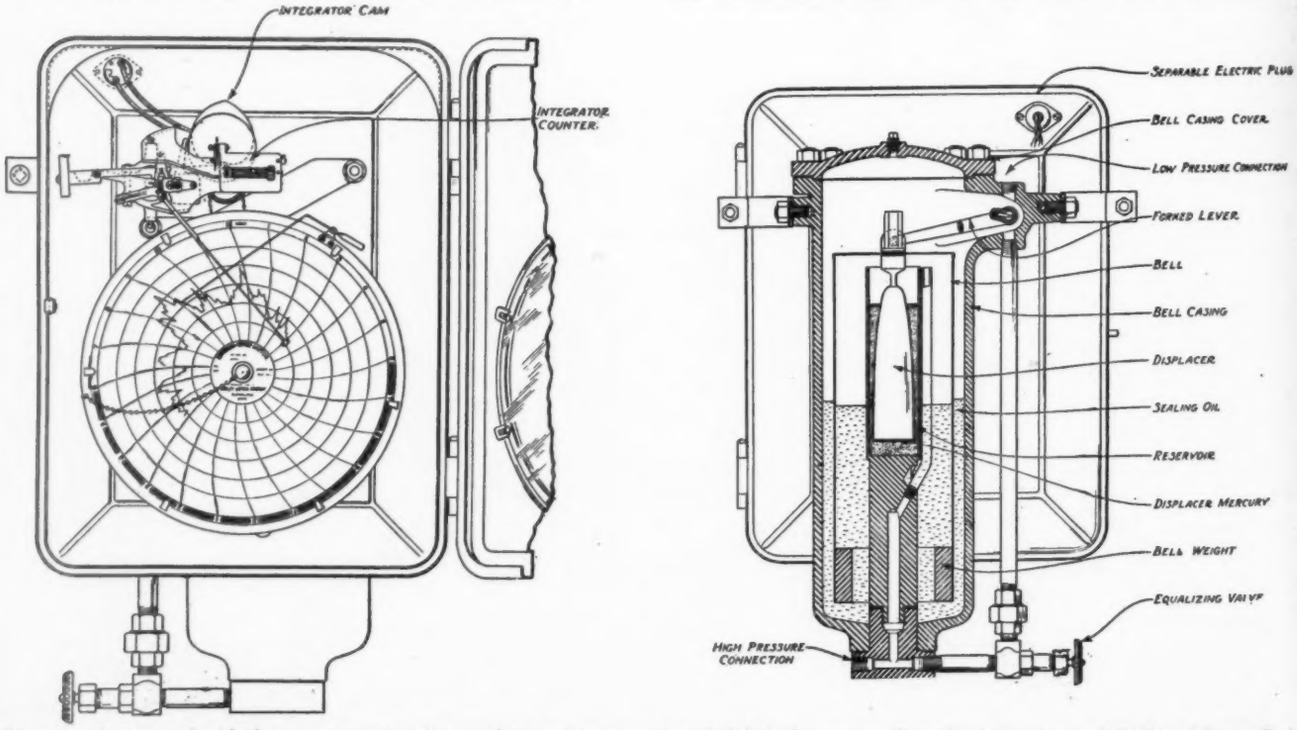


Fig. 6.—An example of the pressure chamber register using an oil sealed bell for measuring air. (Courtesy of Bailey Meter Co.)

flow from the settling chambers back through the pressure piping to the piezometer rings of the Venturi tube. This flow opposes the tendency of solid matter to work into the piezometer rings and pressure piping. The settling chambers, installed between the pressure piping and the copper tubing connecting lines to the register, collect and permit disposal of any solid matter which may work into the piping.

The pressure piping is of 1-inch or larger brass or copper. To facilitate cleaning, crosses are used for fittings, as shown in the illustration. From the settling chambers to the register, ½-inch copper tubing and fittings are suitable.

Open sight feeds are recommended in order to eliminate the possibility of water contamination by a direct cross-connection between the fresh water supply and the sewage system. If preferred, or if the maximum hydraulic gradient is too high to permit the convenient use of open sight feeds, closed sight feeds (see Fig. 5) can be used provided that the water supply to which they are connected is wholly independent of the city water. In some cases, an intermittent type of flushing system is used which utilizes city water. This however, requires the attention of an operator to establish and maintain the cross-connection and disconnect it when manual attention ceases. A flushing connection to the inlet and throat rings of the Venturi tube is also recommended.

When it is necessary to measure the flow through a line in which the hydraulic gradient varies over a wide range, and at the same time to locate the register above the minimum hydraulic gradient, the flow mechanism may be detached from the register and mounted at a lower elevation than the registering instruments. In this case, the movement of the flow mechanism is transmitted to the indicating, recording, and integrating devices by means of flexible cables.

Air Meters

For the measurement of air for aeration in the activated sludge type of sewage treatment plant, or mixing and partial aeration in chemical treatment, the translating mechanism of the register must of necessity function with a small differential head inasmuch as the static pressure of the air itself is low. Under these conditions the pressure chamber type of register is applied, but the sealing fluid usually is oil instead of mercury.

One type of meter used with air is represented in Fig. 6. The differential pressure is applied across the oil sealed bell to which is attached a specially shaped displacer which changes its immersion in mercury as the bell rises and falls with changes in differential pressures. The large size of the oil sealed bell permits operation on very low differentials, yet retaining ample power for the operation of the registering devices. The shaped displacer becomes directly proportional to the rate of flow.

Installation of air meters is a relatively simple task since ½-inch copper tubing with compression fittings, or brass pipe and fittings, may be connected from the primary element directly to the pressure chamber of the register. Settling chambers are not necessary.

Water Meters

For the measurement of clear water the pressure chamber register as described for sewage measurement is recommended. These meters are in service in the water works field on discharge lines from centrifugal pumps, on gravity mains, on branch lines in distribution systems, and in filtration plants to measure raw water, clear water, and wash water and rates of filtration.

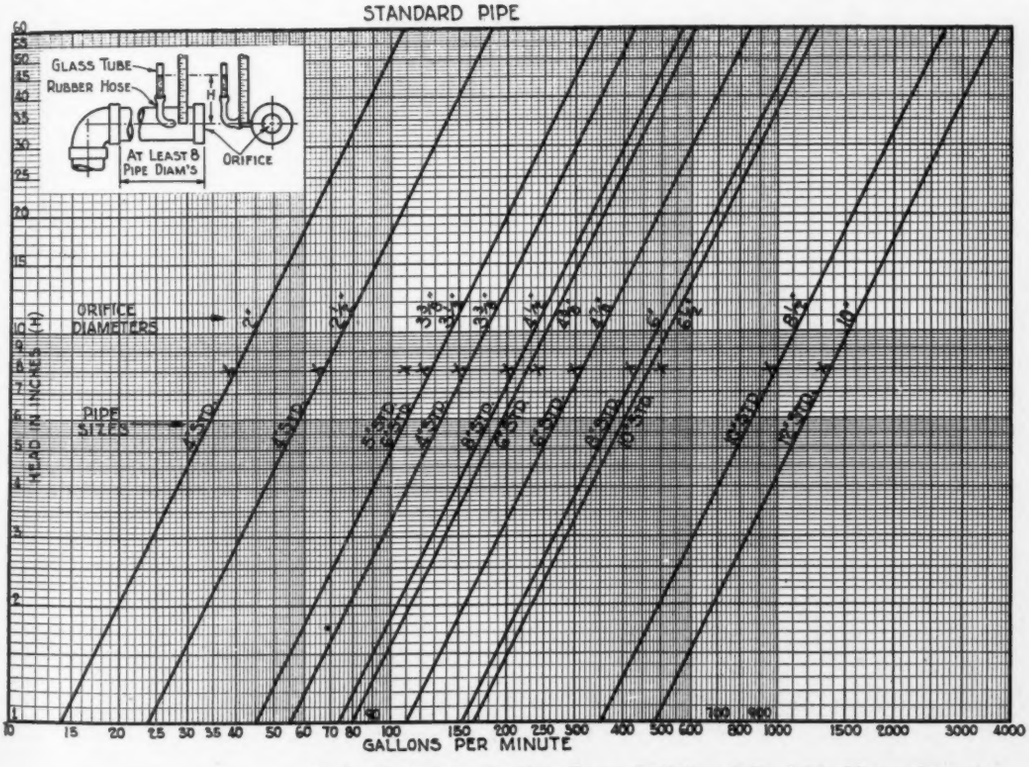
The installation of the register when applied to clean water is as simple as that of an air meter. Direct connections from primary element to pressure chamber may be made with ½-inch copper tubing or brass pipe. Settling chambers are not usually necessary, nor are the sight feed supply systems.

Register Instruments

The register instruments contain relatively simple mechanical or electrical devices which react in accordance with the movements of the flow mechanism to provide indications, chart records, and an integration.

It is advantageous if these instruments are designed so that additional equipment can be easily installed in them at any time for commanding the operation of auxiliary registers, signal devices, and controllers. This feature simplifies expansion of the services rendered by the main register such as operation of remote registers, totalization of flow through two or more influent lines to continuously indicate the capacity at which the plant is functioning. Likewise, for the automatic control by flow or the ratio of quantity of sludge returned to the aeration tanks.

FLOW MEASUREMENTS WITH THE CIRCULAR ORIFICE AT END OF PIPE



To obtain an accurate result in measuring the flow of water with a circular orifice the following conditions are to be maintained: Pipe must be horizontal with no elbows, obstructions or bends within 8 pipe diameters of discharge end; the orifice must be running full of water and "H" be at least one inch above top of the pipe.

Drill and tap discharge pipe on the side through center line for ⅛" pipe connection one foot back from orifice. It is very important that the ⅛" nipple does not extend inside the inner wall of the pipe and should be absolutely flush.

When the rubber hose connection and the glass tube are installed "H" may be measured from the center of the pipe with an ordinary rule.

(This chart from Peerless Pump Bulletin of Food Machinery Corpn.)

THE PARSHALL FLUME FOR MEASURING SEWAGE FLOWS *

It's Theory and Applications

BY NORMAN C. WITTWER

Sanitary and Hydraulic Engineer, Rahway, N. J.

Most sanitary engineers and sewage works operators are familiar with the conventional devices for measuring and recording the flow of water. These comprise the various types of over-fall weirs and the Venturi tube. The Venturi flume in its present form as improved by Parshall[1] is not so generally known, and has not been used to any great extent in connection with sewerage practice.

However, for measuring the flow of water or sewage in open channels, this device has several distinct advantages:

(1) The accuracy of measurement is at least comparable with that of any of the standard forms of weirs.

(2) The loss of head is relatively small and, varying with degree of submergence, becomes approximately one-fourth the loss of head for a standard weir.

(3) It will withstand a high degree of submergence without affecting the rate of free flow discharge.

(4) Unlike the weir, it is little affected by condition or velocity of approach.

(5) Unlike the weir, it is self-scouring, and operates without trouble in waters carrying large amounts of sand or grit.

(6) It is not easily altered in dimensions for wilful erroneous measurements.

(7) It has all plane surfaces and is easily constructed in most channels.

One-Half of a Parshall (10-Ft.) Flume, Looking Down Stream to Throat Section, Providence, R. I.

Indicating, Integrator and Recording Flow Instrument, Actuated by Parshall Flume, Providence, R. I.

(8) Operation is simple because it has no adjustable or moving parts.

(9) For most installations, the measurement of but one head (the inlet) is necessary.

Collaborating with other experiments, Ralph L. Parshall, Senior Irrigation Engineer of the Bureau of Agricultural Engineering, U. S. Dept. of Agriculture, after making literally thousands of calibrations at the Fort Collins, Colo., Experiment Station, devised the Venturi flume as it is known today, calling it "The Improved Venturi Flume."[1] The American Society of Civil Engineers in 1930 officially changed its name to "The Parshall Flume" in honor of its originator. It was originally developed for use in connection with irrigation, and has since found wide application in the central-west and western irrigation districts.

The Parshall Venturi flume has been applied to the measurement of sewage flows at the Providence, R. I., Sewage Treatment Plant, where a flume with a ten-foot wide throat is being used to measure flows varying from 5 to 120 million gallons per day.[3] At the Walden, N. Y., Sewage Treatment Plant a flume with a 9-inch wide throat is being used to measure flows varying from 5,000 to 1,200,000 gallons per day.[4] At Newark, N. Y., a flume with a 12-inch wide throat is being used to measure all the sewage passed through the sewage treatment plant.[5] Some years ago the writer incorporated a Venturi flume with a 6-inch wide throat into the design of a 1 m.g.d. sewage treatment plant for Maple Shade, N. J., where the available head through the plant was very limited.

Applications

The Parshall flume is particularly advantageous in measuring sewage where the available head is limited, and a nearly flat

*From WATER WORKS AND SEWERAGE, July, 1936.

TABLE 1—LOSS OF HEAD FOR GIVEN DISCHARGES, THROUGH PARSHALL FLUMES AND VARIOUS TYPES OF WEIRS

Discharge Sec. Ft.	Parshall Flume* 6-In Throat, Ft.	1-Ft. Throat, Ft.	2-Ft. Throat, Ft.	4-Ft. Throat, Ft.	Standard Rectangular Weir— 6-In. Crest, Ft.	1-Ft. Crest, Ft.	2-Ft. Crest, Ft.	4-Ft. Crest, Ft.	Standard Cipolletti Weir— 6-In. Crest, Ft.	1-Ft. Crest, Ft.	2-Ft. Crest, Ft.	4-Ft. Crest, Ft.	90 Triangular Notch Weir, Ft.
0.10	0.03	...	...	...	0.15	...	...	...	0.15	...	...	...	0.27
0.50	0.11	...	...	...	0.46	0.29	0.18	...	0.43	0.28	0.18	...	0.52
1.00	0.18	0.13	...	...	0.74	0.46	0.29	0.18	0.64	0.44	0.28	0.18	0.69
2.00	0.31	0.21	0.15	...	1.16	0.75	0.46	0.29	0.96	0.69	0.45	0.28	0.92
3.00	...	0.27	0.18	...	...	0.99	0.61	0.38	...	0.88	0.58	0.37	1.08
5.00	...	0.39	0.24	0.13	...	...	0.86	0.53	...	...	0.82	0.52	1.32
7.50	...	0.50	0.31	0.20	...	...	1.13	0.70	...	...	1.06	0.68	...
10.00	...	0.60	0.39	0.25	...	...	...	0.85	...	...	1.27	0.83	...

*70% submergence.

hydrulic gradient is mandatory. Table I illustrates comparative losses of heads for free-flow through Venturi flumes and over various standard types of weirs.

TABLE 2—STANDARD DIMENSIONS AND CAPACITIES OF PARSHALL'S FLUME

(Letters refer to Figure 1)

Throat Width W	A	⅔ A	B	C	D	E	F	G
Ft.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft.	Ft.	In.
0.5	2 1¼	1 4⅞	2	1 3½	1 3½	1	2	4½
1.0	4 6	3	4 4⅞	2	2 9¼	2	3	9
2.0	5	3 4	4 10⅞	3	3 11½	2	3	9
3.0	5 6	3 8	5 4¾	4	5 1⅞	2	3	9
4.0	6	4	5 10⅝	5	6 4¼	2	3	9
5.0	6 6	4 4	6 4½	6	7 6⅝	2	3	9

As stated above, the accuracy of the Parshall-Venturi flume is comparable with that of the standard weirs, and it can be used for any purpose which the standard weirs serve. Its principal applications may be listed as follows:

(1) To measure the entire flow through a plant or pumping station.

†(2) To proportion the flow through units operating in parallel.

†(3) To serve as a control for the automatic dosage of chlorine and other chemicals in proportion to the flow of sewage.

†(4) To measure and control the amount of return sludge in an activated sludge plant.

(5) In a sewerage district, to measure the sewage flows contributed by the various member municipalities.

Principle of the Parshall Flume

By examining Figure 1, it will be seen that the flume converges to its narrow or throat section. As the water approaches the throat, the velocity is constantly increased. It is still further increased after passing over the "crest," which is the junction of the level upper floor and the throat door at E. With the momentum thus acquired, the water is carried upward over the sloping floor of the diverging section and on through the flume. This unrestricted condition of flow is called "free flow."

If the grade of the channel downstream from the flume is reduced, the water, after passing through the flume, is resisted and checked in velocity, causing a backing up into the diverging section. If the water is backed up sufficiently to cause the surface

†The Parshall Flume, of itself, naturally can not perform duties 2, 3 and 4 unless the accessory-mechanical equipment, similar to that employed with Venturi Tubes, is provided.

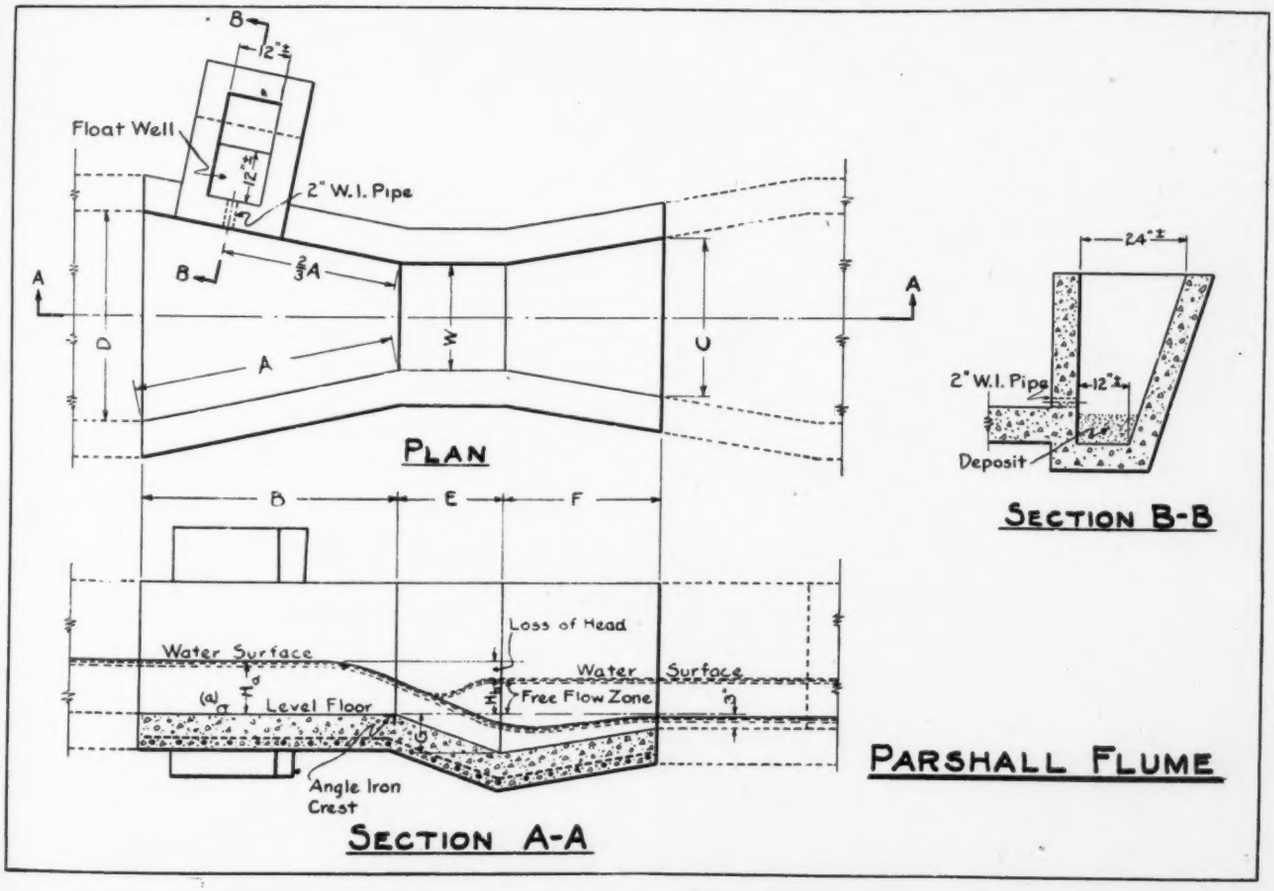
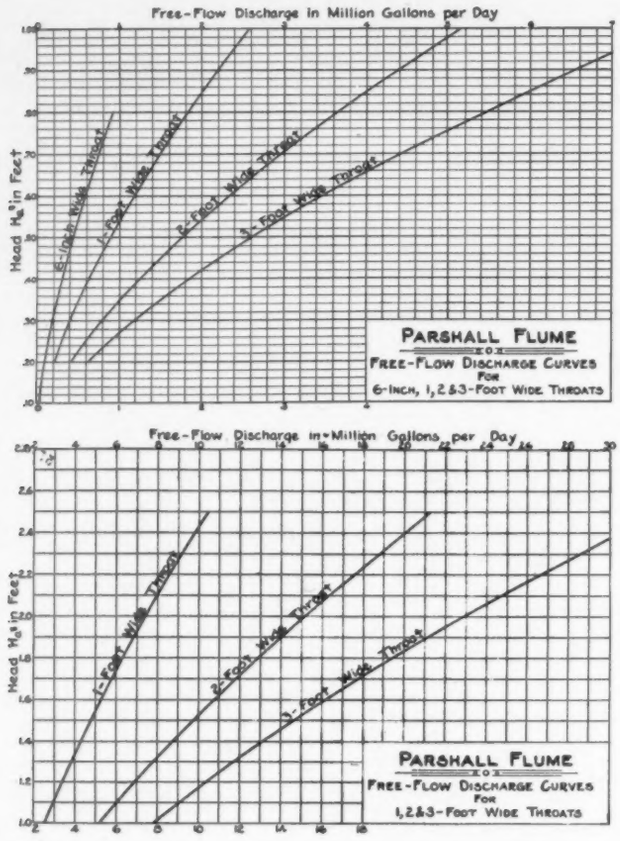


Fig. 1—Parshall Flume in Plan and Section


Free-Flow Discharge in Million Gallons per Day
Head H_a in Feet
6-Inch Wide Throat
1-Foot Wide Throat
2-Foot Wide Throat
3-Foot Wide Throat
PARSHALL FLUME
FREE-FLOW DISCHARGE CURVES FOR
6-INCH, 1, 2 & 3-FOOT WIDE THROATS
Free-Flow Discharge in Million Gallons per Day
Head H_a in Feet
1-Foot Wide Throat
2-Foot Wide Throat
3-Foot Wide Throat
PARSHALL FLUME
FREE-FLOW DISCHARGE CURVES FOR
1, 2 & 3-FOOT WIDE THROATS

Figs 2a and 2b—Discharge Curve of Parshall Flume

elevation of the water in the diverging section to attain the same level as that of the crest, a condition of zero submergence is said to exist. Still further backing up of the water will cause the elevation of the water surface in the diverging section to rise, producing what is called a hydraulic jump. Under such conditions, the flow is said to be submerged, the percentage of submergence being the ratio of the throat head (H_b) to the upper head (H_a), both being measured from the crest as a datum. The discharge of the flume is not reduced by moderate percentages of submergence, and is considered as having the characteristics of free-flow below the critical percentages. The 6-inch flume has free-low characteristics up to 50 per cent submergence, and the 1-foot, 2-foot and 3-foot flumes up to 70 per cent submergence. For ordinary installations, Parshall flumes should be installed with freeflow conditions.

Free-Flow Formula: For free-flow characteristics, as stated above, only the gage reading (H_a) at (a) need be measured.

For the 6-inch flume, the formula for free-flow discharge is:

$$Q_1 = 2.06\ H_a^{1.58}$$

or $$Q_2 = 1.331\ H_a^{1.58}$$

For 1 foot to 10-foot flumes, the formula for free-flow discharge is:

$$Q_1 = 4\ W\ H_a^{1.522W^{0.026}}$$

or $$Q_2 = 2.585\ W\ H_a^{1.522W^{0.026}}$$

where Q_1 = Quantity of flow in second-feet.
Q_2 = Quantity of flow in million gallons per day.
W = Width of throat in feet.
H_a = Upper head in feet.

A 10-Ft. Parshall Flume in Service. The Hydraulic Jump Just Downstream of the Throat Is Plainly Visible

Figs. 2a and 2b are convenient charts for obtaining free-flow discharges for small and medium size plant needs. While experiments have shown the reliability and accuracy of the 6-inch flume above an H_a value of .80 feet, it is advisable to use a larger flume for flows in excess of 1 m.g.d.

Construction: By referring again to Figure 1, it will be seen that the flume has only plane surfaces. It may be constructed of concrete, or if for temporary use, of dressed cypress or white pine properly braced across the top. Two-inch lumber is recommended for the bottom and sides of the timber flume, with 4 by 4-inch sills and posts. If constructed of concrete, the crest should be formed by casting a medium size angle iron in the floor, as shown in Figure 1.

Measuring Sewage Flow: The measuring or recording device may be any of the home-made or commercial types of apparatus ordinarily used for this purpose. It may be an indicating staff gage, a graphic recording float gage mounted over the float-well. Or, in larger permanent installations, an indicating, recording and integrating instrument may be located at a point not far removed from the flume. The readings can be electrically transmitted to distant points such as has been successfully done at the Providence, R. I., Sewage Treatment Works.

Summary:

1. The Parshall flume is adaptable to the measurement of sewage flows.
2. It particularly meets low-head requirements.
3. It is simple and easy to construct.
4. Its maintenance requirements are negligible.
5. It can be connected with any of the conventional measuring and recording instruments.

Acknowledgment: To Mr. Ralph L. Parshall and the Colorado Experiment Station, the author wishes to express his appreciation for their kind permission to make use of much of the data which appeared in bulletins dealing with the Parshall (Venturi) flume.

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PRACTICAL ELECTRICITY IN THE PLANT

The A. B. C.'s of Electricity for the Water and Sewage Works Man

By MARSDEN C. SMITH

Engineer Water and Electricity, Department Public Utilities, Richmond, Va.

Taken from a series of short articles by Mr. Smith, dealing with the A.B.C.'s of practical electricity for water works and sewage plant operators.*

The author, a graduate electrical engineer, is a well known water works operator. He is, thereby, peculiarly well qualified to present these discussions, which should be of considerable benefit to operators and designers less thoroughly grounded in electrical matters.

If there are points in his contributions not clear to the reader, Mr. Smith offers to answer inquiries.

THE increasing use of electricity in water and sewage treatment plants produces problems of design, operation and maintenance with which the engineer in charge is generally but little familiar. Fortunately, while advanced electrical engineering is a very involved subject, a helpful and useful knowledge of its fundamental principles can be obtained quite readily by the trained personnel of such plant. To that limited end the presentation of this series of articles* is confined.

The Author

PART I—ELECTRICAL UNITS

The Volt

One of the most important units of electricity is the Volt. It is the unit of electrical *pressure*. Just as we measure water force or pressure in units of pounds per square inch or feet of head, the unit of electromotive (electric moving) force is the volt. In equations, its symbol is E. Voltage is sometimes expressed in print as the emf—abbreviation for electric-motive force.

Standard voltages are 110, 220, 440, 2,200, 4,000, and 13,200. The individual for whom these articles are intended is rarely concerned with voltages in excess of 2,200. Furthermore, the 110 volt standard is now in the process of change, and seems to be quite generally replaced by a standard of 120 volts.

Extra-heavy fittings and greater precautions are necessary with greater water pressures; so too, must greater care be taken both of life and property when higher electrical pressures are used. However, pressures of as little as 110 volts, in common domestic use, may prove fatal and care should always be taken to avoid personal contact with even these relatively low pressure circuits.

Most electrical apparatus is designed to operate at one of the above mentioned standard voltages. The use of other than these standards is both unnecessary and uneconomical. Incandescent lamps are generally rated at from 110 to 125 volts in five-volt increments. They may be obtained designed for 220 volts, but such lamps are not recommended except where no 110-volt service is available. Even then safety and economy demand the use of 110-volt lamps if possible.

Some Practical Considerations

Lamps are very sensitive to voltage change; and the operator should see that the lamps are purchased for the circuits on which they are to be used. For example, if the average voltage at the station is known to be 118 volts, 120-volt lamps should be used. Here the use of 110-volt lamps would increase the lamp replacement cost by almost 300 per cent.

Motors are not nearly so sensitive to voltage change as are lamps and will operate successfully at applied voltages within 10 per cent above or below normal rated voltage. Greater voltage variation will generally cause excessive heating and unsuccessful operation.

Small motors (less than 5 horse-power) are usually single phase and operate at standard lamp voltages. Large motors, 5 to 50 H.P., are cheaper when designed for 220 or 440 volts. Larger than 50 H.P. should be designed for 2,200 volts. Of course, local conditions may change these recommendations. One large plant has motors from 3 to 300 H.P. The station designers used 2,200 to 440-volt transformers; motors between 50 to 300 H.P. were ordered for 440 volts. A second set of transformers reduced the 440 volts to 220 volts for the smaller motors (up to 50 H.P.). Certainly this is unfortunate, because the larger and more expensive motors would have been of less first cost if designed for 2,200 volts, and the 2 to 5 per cent transformer losses, which materially increases operating costs, would have been saved. The smaller motors could all have been 440-volt type, thus here again would have been saved the second transformer losses. Here we see an evident error that a better understanding of the problem of electricity in design would have avoided.

Other than electrical engineers often fear the use of 2,200 volts. It is true, that there is no need for this higher potential, unless the size and number of motors justifies its use. However, where the total of as much as two or three hundred horse-power is required for motors larger than 50 H.P., the higher potentials are certainly advisable.

The relative advantage of the use of 220 or 440 volts as the operating voltage for the smaller motors is not so definite. However, for larger plants 440 volts seems more desirable. Safety requires the same care with 220 volts as with 440 volts, and a much wider range of motor sizes can be more economically operated at this than at 220 volts.

The Ampere

The second important unit of electricity to be considered is the Ampere.

It is the unit of electrical *rate of flow*. We are familiar with the various measures of the rate of flow of liquids; gallons per minute, etc.; so we should think of the unit rate of flow of electricity as the ampere. In equations its symbol is generally (I). In print Amperes are sometimes abbreviated to "Amp." Larger pipes are required to carry larger rates of flow of water economically; so too, larger wires are needed to carry larger currents (amperes) economically. Small pipes may be uneconomical because friction causes too great loss of water pressure. In exactly the same way, wires may be too small for the amperage (current flow) and cause an uneconomical loss of electrical pressure (voltage drop).

There are no standard currents as in the case for the voltage rating of electrical apparatus. Each appliance, lamps, heating devices, etc., takes from the circuit a current dependent upon its design and lack of resistance to flow. Motors require, for example, a current that varies with the load. All electrical apparatus (except lamps) should have its normal current rating stamped upon its nameplate. Lamp current is determined by dividing its watt rating by its rated voltage.

However, there are certain appliances such as wire, fuses and switches that are rated in terms of the current they may safely carry; thus currents are to this extent standardized. The plant manager should realize that these current ratings are fixed by the National Electric Code, and he should not permit greater current to flow through accessories than the limits established by this code. Oftentimes circuits are fused far beyond the rated capacity of the wire, which is supposedly being protected by the fuse. Such practice is both uneconomical and dangerous.

Most appliances, including motors, are connected between the supply lines, that is, in parallel. In this way the circuit voltage is impressed upon each appliance, causing a current to flow through the appliance of a quantity dependent upon its rating and load. These increments of current are added, hence the supply wires carry greater and greater total current as we work back toward the source of power. For example: Five 1,000-watt

*From WATER WORKS AND SEWERAGE, issues of October and December, 1936; February and April, 1937.

lamps rated 100 volts each require 10 amperes. Let us designate these as numbers one to five, from that nearest the supply to the most remote. Both wires between the supply and the first (No. 1) lamp carry 50 amperes; between 1 and 2, 40 amperes, and so on until between 4 and 5 the current has reduced to 10 amperes, or that required by No. 5—the last lamp. They all have (practically) the same voltages as the supply applied to their terminals.

Some Practical Considerations

When installing new apparatus there are two considerations of great importance: (1) Use wire of ample conductor size. (2) Employ insulation having a large factor of safety. For low potential circuits (less than 600 volts) 30 per cent pure rubber insulation will generally prove more economical than the standard code insulation. Particularly is this true in water and sewage treatment plants due to the prevalence of dampness in such locations. For 2,200-volt circuits rubber insulated cable is more easily installed than is varnished cambric cables. Rubber depreciates must more rapidly when subjected to heat and grease or oil than does varnished cambric, but it is less affected by moisture. For this reason, varnished cambric is never used without some form of outer coating, usually lead. Modern synthetic resins and other compounds are rapidly proving their value for use as the outer protective coating, materially lessening the installation difficulties. These coatings are deserving of consideration.

In general, where expert electrical maintenance is not available, the proper thickness of 30 per cent pure-rubber insulation, on conductors of adequate size for the current they will ever have to carry, will certainly well repay the increased investment cost. Where such expert maintenance is available, varnished cambric insulation may prove better for 2,200-volt circuits.

The Ohm

The unit of electrical resistance is the Ohm. In equations its symbol is (R).

If we close the spigot, even though there be water pressure at the valve, no water can flow because the resistance is too great. The same result is obtained when opening an electric switch; the pressure (voltage) still exists but the resistance (ohms) become so great that no current (amperes) can flow. This is an example of localized resistance.

Electrical resistance may be distributed, in fact *is* distributed along the conductor just as is the pipe resistance to water flow proportional to its size, length and condition. Fortunately, in electrical circuits the loss of voltage (pressure) is always directly proportional to the resistance and rate of current flow. Therefore, the loss of power (to be discussed in the next article) is proportional to the resistance and the square of the rate of flow or current.

An electrical device, such as a lamp, does not use or destroy current in the sense that an oil lamp consumes oil, but by its relatively high resistance limits the current that may flow as a result of the impressed electromotive force—voltage. Thus we have the simple but important equation known as Ohm's Law:

$$E = RI \quad \ldots\ldots (1)$$

There are no standards of resistance; however, the established resistance per unit length of electrical conductors and resistance alloys may be found in any electrical engineer's handbook.

Direct vs. Alternating Current

Formula (1) applies to circuits that contain resistance only, or in which the frequency is zero, as in the case of direct current. This term frequency must now be understood. If the polarity between two wires (A and B) of a circuit is not changed, the current flow will always be in one direction in the wires, thus constituting what is termed direct-current—(D.C.). If we alternate wires A and B from one side of the source to the other, once each ½ second, the direction of current flow in A and B will reverse once every ½ second, and will begin to flow in the original or *same* direction in a given conductor once every second. Electrically we would say that there was being produced "An electromotive force (current) having a frequency of one cycle per second." Fundamentally that is the difference between alternating and direct currents. Modern alternating currents closely follow the sine law in their time-potential value; and the standard frequency in this country is now sixty cycles per second.

When direct current is applied to a coil of copper or other wire (having resistance R) wound around iron, if the current and voltage be carefully measured, equation 1 will be found to apply. When an alternating voltage is applied this equation no longer can be used. This is because any magnetic circuit is an inductive circuit, and the effect of an inductance is to divide the alternating current into two components which are at right angles to one another. Hence to obtain the same current through the coil when an alternating voltage is applied, a greater voltage is required than when a direct voltage is used. So for alternating current circuits equation 1 becomes:

$$E = ZI \quad \ldots\ldots (2)$$

in which Z is the impedance of the circuit.

Many devices, such as heating appliances and lamps have little or no inductance; hence may be used on either direct or alternating current circuits of the rated voltage; but inductive devices, such as transformers and motors, cannot be used on direct current circuits unless especially designed for the purpose.

Transformers

The engineer for whom these articles are intended rarely is concerned with the use of transformers; however, a brief discussion of them is advisable. The standard transformer consists of two stationary coils of wire insulated from one another and wound around a common iron core. A special class, the auto-transformer, commonly used for motor starters, has only one winding with connections to some desired turn between the two end turns.

Of the winding in the auto-transformers, the turns connected to the power supply is the primary; the secondary winding is connected to the load. The voltage change between the primary and secondary is in direct ratio to the number of turns used in the two windings; conversely, the current is in the inverse ratio to the number of turns. Hence a transformer may be used to increase voltage as readily as to reduce it—the so-called "step-down." Many deaths have resulted from opening the high voltage switch, assuming the transformer "dead," when in fact the 110-volt side was still energized thus producing normal high voltage in the primary.

Instrument transformers are especially designed to accurately reduce the potential or current, as the case may be, for metering and other purposes. Care should be taken to always connect the secondary terminals of current transformers together with wire (short-circuit them) if the secondary circuit must be disconnected for any purpose while the primary continues to carry current.

It is well to know that transformers, if kept cool enough, can safely carry much greater than rated loads. Cold winter weather and artificial ventilation around the tanks is effective, but hot locations and days are dangerous. Tank temperatures should never exceed 90 degrees C. Contamination of the oil by dirt or even traces of moisture must be avoided. In larger units the oil should be examined monthly by a competent inspector.

The Watt

Another very important unit of electricity is the Watt, which is the unit of electrical power. The more commonly used unit is the Kilowatt, which is one thousand watts. The symbol for the Watt is (W); for the Kilowatt (KW). The mechanical unit of power is horse-power; one horse-power (H.P.) is the equivalent of 746 watts or 0.746 kilowatts. Due to the fact that the efficiency of small motors is approximately 75 per cent, the input in kilowatts is, by coincidence, closely the same as the mechanical output in horse-power.

With direct current, electrical power is the product of the current (I) and the voltage (E). Thus we have:

$$P = EI \quad \ldots\ldots (3)$$

However, substituting for (E) from equation (1), wherein $E = RI$, we have:

$$P = RI^2 \quad \ldots\ldots (4)$$

Or similarly, substituting for (I) where $I = \frac{E}{R}$ in the same equation:

$$P = \frac{E^2}{R} \quad \ldots\ldots (5)$$

Now, it becomes evident that electrical power varies directly with both current and voltage, if resistance is not considered, but as the square of either (E or I) if the resistance is considered.

PART 2

POWER FACTOR; ITS SIGNIFICANCE

With alternating currents equation (3) becomes the more familiar form, and—

$$P = EI \cos \theta \quad \ldots\ldots (6)$$

In this equation the Cos θ is designated as the power-factor. If an alternating current circuit contains resistance only (no capacity or inductance) the angle θ becomes zero; hence, its

cosine, which is the power-factor becomes unity. Electrical installations in water and sewage treatment plants rarely contain sufficient capacity (condenser action) to be of any practical effect, hence we may omit further reference to "capacity" in these articles. Inductance, however, is of great importance, and in practical installations may reduce the power factor as much as 30 per cent.

The actual mathematical value of the power-factor of practical circuits is difficult to compute; however, it is well for the engineer to have some idea as to the values that may be expected. Incandescent lamps and heating devices, since they contain but little inductance, are virtually non-inductive; hence, their power-factor closely approaches unity. Motors and transformers vary through very wide limits. Of course, a transformer being highly inductive when delivering no load, its power-factor is quite near zero; but, at rated load the power-factor becomes quite nearly that of the circuit being supplied by the transformer. Small motors, up to 5 h.p., require power at not more than 60 per cent power-factor; particularly so when operating at light loads. Large induction motors, at full load, now may operate at as high as 94 per cent; and, synchronous motors, more fully discussed in coming articles, may be operated almost as desired.

The objection to low power-factors is that larger currents are required for the same power, thus increasing power losses in the whole electrical system. Furthermore, low power-factors cause much wider voltage variations than do greater loads with higher power-factors. For this reason many power companies offer reduced rates to those consumers whose apparatus constitutes a load having a favorable power-factor. This fact may be of value to many larger operators. It is true, however, that plant operators can exercise but limited control over the power-factor of their stations except through the selection and operation of the motors. This phase of the subject will be later discussed when motors and their characteristics are considered.

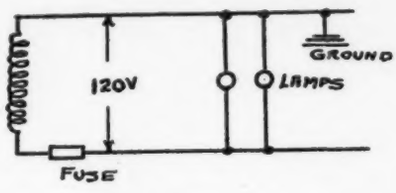


FIG 1

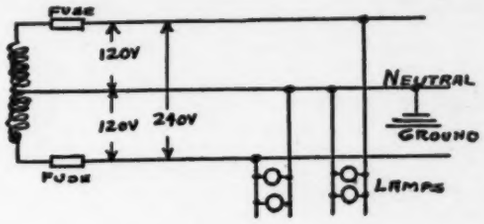


FIG 2

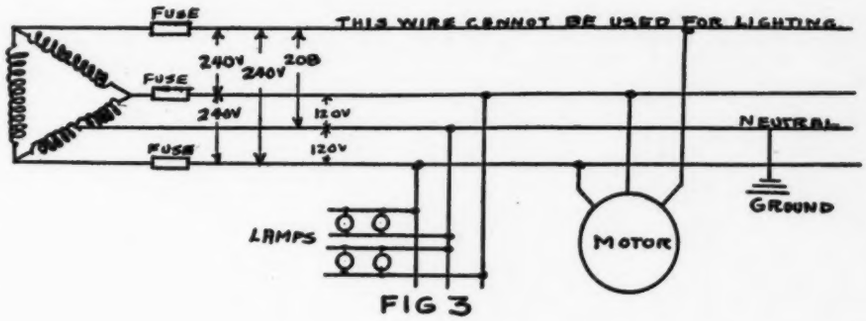


FIG 3

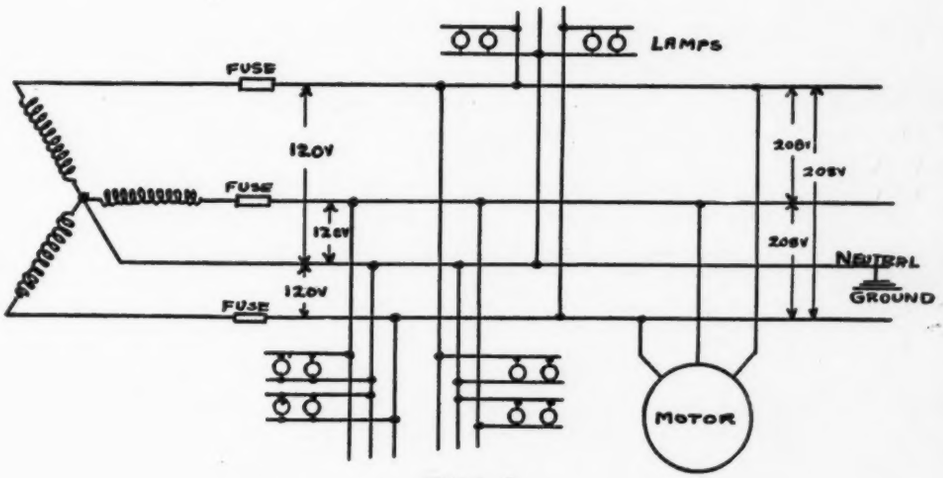


FIG 4

Circuits: *Figs.* 1, 2, 3 *and* 4

The Kilowatt-Hour

The kilowatt-hour (KwHr) is the unit by which electric power is generally sold. As its name implies, it is the average power consumed, in kilowatts, multiplied by the number of hours involved. For example: if an electric iron is operated for two hours at average rating of 600 watts, there is used $600 \times 2 = 1200$ watt-hours, or 1.2 KwHrs.

The volt-ampere (VA) is the product of the volts and amperes of a circuit or an appliance, without reference to power. Thus, the transformer is always rated in kilo-volt-amperes (KVA) because its parts can be designed for the voltage and current value desired, but the power-factor of its load may vary through wide limits. Thus we see that:

$$KW = KVA \times \text{Cos } \theta \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Hence, if we are to know the safe load for a transformer rated at 100 KVA, we must first determine the power-factor of the load to be connected. If we may assume the load to be one-half lamps and one-half small motors; we may approximate the average power-factor to be 82 per cent. Hence, by equation (7) we find $Kw = 100 \times 0.82$ (82 Kw) to be the safe load for this case.

The Cos θ, which we now recognize to be the power-factor, is actually the cosine of the angle of time-phase displacement between the current and the voltage of an alternating current circuit containing "capacity" or inductance.

Circuits

The term, "phase," is also applied to designate the circuits of an alternating current system. In the "Single-Phase" system the *voltages* are in the same time-phase in all parts of the system. In the "Two-Phase" system, the two voltages are 90 degrees apart. In the "Three-Phase" system they are 120 degrees apart.

In another sense, there are in effect one or two or three circuits in the single, the two or the three-phase systems. Of course, the power-factor may be different in each phase; hence the currents in the phases may not be of exactly the same angular difference as the voltages producing these currents.

The simplest circuit is that comprising the single-phase (two-wire) system, as in Fig. 1. This is used for the final branch circuit of larger systems, and in case of small loads, including most residences, it is always used.

The single-phase, three-wire system is next in capacity and in frequency of use. Single-phase, two-wire branches are connected thereto as shown in Fig. 2. The evident advantage of three wires over the two-wire system is that when loads are

balanced, the neutral carries no return current, hence the lamps and appliances operate at 120 volts, whereas the circuit operates at 240 volts. In this way twice as much power can be carried over the same wires, by merely adding one additional wire.

Grounding Practice

The neutral must be grounded. It should be the same size as the phase wires; and, it must *not* be fused or connected to any switch, and the wire used for the neutral must have white covering for identification, and the neutral must be connected to the white screw in all receptacles. In the single-phase, two-wire system one of the wires must be grounded and the same rules as given for the neutral conductor wire must be observed.

(Grounding practice as it affects water works piping will be given some discussion at a later point in this article.)

Three-Phase Standard for Heavy Duty

The three-phase (three-wire) system is standard for motor loads. If lighting is required, the neutral of one transformer (made larger to carry the additional load) is brought out as in Fig. 3. Most power companies limit the single-phase load that may thus be supplied to 50 KVA. In addition, this method of supplying the lighting loads makes service interruptions more frequent because of the necessity for grounding one of the transformer windings. Perhaps most serious of all is the objectionable flicker in the lights obtained when starting motors, particularly elevators connected to the system. Of course, economy often rules and hence this system is frequently used; but unless the motors are relatively small, and are started very infrequently; it is undoubtedly better to separate the lighting and very small motors from the power system.

The formula for power in the different systems, with balanced load, is given in the following table:

System	*Power*		*Max. Volts to Ground*
Single-Phase (Two-Wire)	$P = EI\cos\theta$	Here E=120	120
Single-Phase (Three-Wire)	$P = EI\cos\theta$	Here E=240	120
Two-Phase (Four-Wire)	$P = 2EI\cos\theta$	Here E=120	120
Three-Phase (Delta)	$P = \sqrt{3}EI\cos\theta$	Here E=240	207.8*
Three-Phase (Y)	$P = \sqrt{3}EI\cos\theta$	Here E=207.8	120

*Volts to ground on lighting circuits is 120.

The two-phase (four-wire) system is so little used that no discussion is necessary.

PART 3—CIRCUIT PROTECTION

Fuses and all electrical circuit-breakers are similar in function to the safety valve on a boiler; and hence they should be seriously considered. They are all intended to open the circuit, thus stopping the flow of current, should the current exceed a predetermined or dangerous rate through these safety devices.

While the problem of circuit protection becomes at times quite involved, still there is much that can here be discussed to advantage. In the first place, the Natinal Electric Code is now almost universally accepted as the authority for the safe utilization of electricity in all except central station systems. Consequently, the engineer should obtain a copy of this useful and important publication.

Fuses and Circuit Breakers

Fuses are the cheapest and simplest of all protective devices. They consist of a piece of relatively high resistance alloy wire or tape, designed to melt, and thereby part, at the current at which the fuse is rated. The wire is enclosed in a suitable flame-proof case to prevent ignition of surrounding materials at the time the fuse flashes and melts. The use of fuses is now confined almost entirely to circuits the importance of which does not justify the more expensive and accurate devices. The type now approved, known as the "refillable type," permits the renewal of the fuse link, using the expensive part (the cartridge) over and over again.

For those applications in which the replacement of fuses is frequently necessary, thermal relays or air circuit breakers are to be recommended. Motor circuits fall in this classification. Thermal relays and circuit breakers can permit a greater than rated current pass for a short time, as during the starting period of a motor, and therefore are of especial advantage for this service. The current capacity as well as the voltage ratings of this class of protective devices are limited, and when greater limits are needed the oil circuit breaker must be used.

The oil used in circuit breakers must be especially selected for this service; and no other oil should ever be used. This precaution is essential for the reason that the oil must have high insulation value, high flash point, low carbon content, and wide temperature viscosity constant—all in order to quickly quench the arc that is formed with each opening of the contacts.

Relays

The overload operation of an oil circuit breaker is usually actuated by an auxiliary device known as a relay. Relays may be of several types: the instantaneous, the inverse time limit, and others. The modern relays are truly marvelous devices; however, the types needed by the water works plants are, in the main:

(1) *The Instantaneous Type*—dash-potted relays with direct mechanical trip. Here a coil which carries all or a definite part of the load current raises a solenoid when the current flow exceeds a predetermined value. The rising solenoid mechanically releases a trigger, which in turn permits the oil circuit breaker to open. An oil-filled dash-pot retards the solenoid movement. The dash-pot opening is adjustable, hence the time for opening with a given over-current can be selected as desired. The oil in the dash-pot should be inspected at intervals and replaced if dirt or sludge has accumulated. While rather crude, this device is sufficiently accurate for the protection of most small motor circuits.

(2) *The Air Bellows Type*—This type is not much used now. An air bellows, with an adjustable escape valve, is substituted for the oil dash-pot described above.

(3) *The Induction Type*—This relay is more expensive than those above mentioned, but its use is justified in the protection of all important cicuits.

With the induction relay, when the current exceeds the desired value, the torque on an aluminum disc, mounted on the same shaft with the relay contacts, causing the shaft to rotate. Such rotation causes the opening (some cases the closing) of the relay contacts, which in turn electrically energize the main tripping coil on the circuit breaker. The advantage of this type is that the time of opening the main circuit breaker can be determined to a fraction of a second; also, that the limits of control are so wide that these relays, with suitable current transformers, become almost universally applicable and highly accurate protective devices.

To repeat, too much care cannot be given the subject of circuit protection. Over-fusing (use of fuses with too great capacity) of circuits is dangerous and uneconomical. Noting a too frequent operation of the overload, protection of any appliance warrants prompt investigation. The source of the trouble should be remedied by correction, rather than following the easiest path of using too large circuit protection to overcome an annoying operating circumstance.

Grounding—Its Essentiality

It is no exaggeration to say that without adequate grounding, satisfactory electrical service would be virtually unknown. In addition, safety would be a word more than a reality. Even so, many groundings are so deficient in quality as to become actually a hazard instead of a safety effect. Many persons have been swindled into paying for a false sense of security when installing lightning rods having many ornamental glass balls but no grounds. Thereby the victim is actually inviting the lightning to strike the house but offering no protection by way of a cable or rod to conduct the electric discharge into the earth and there dissipate it.

Grounds should be carefully made. Use not less than No. 2 B&S gauge copper wire. Several grounds are preferable to a single ground in order to lessen the chances of broken connections. Use the water pipe system; the larger the pipe, the better. Do not use the gas, gasoline or oil pipe lines. Be sure the connection between the wire and pipe is electrically and mechanically as perfect as possible. If no pipe system is available, drive at least three 1¼-inch pipe, or equivalent copper rods, *well below the moisture line* in the earth. A good test is that the driven ground connection, when shorted, should blow a 30-ampere fuse at 120 volts.

Much discussion has recently been raised in the water works field as to the effects of attaching the electric circuit "neutral" wires to the water pipes. There is no question that the damage done to water systems by stray direct currents, as from street railways, has been indeed enormous. Here we have electrolysis at its worst, and the destruction of the metallic pipes at spots where the current leaves the pipes is rapid. This condition is inexcusable and should be prohibited everywhere.

However, in the alternating current system the damage is not so evident, and many doubt its *real* existence—or at least its seriousness. Also it is quite possible that were all connections between electrical and water systems removed, electrical service as we know it today would be a thing of the past. And even should such action force the electric companies to seek other means of obtaining the necessary protection now provided by these ground-

ing attachments, the water systems would be subject to the same distress now *debatedly* suffered. It would seem certain that more severe difficulties would be caused by the same currents finding their way to the water system in a then uncontrolled routing and dissipation which present practices have been designed to effect.

The necessity for grounding the electric circuits is to prevent dangerous high-potential voltages (through mistakes or accidental contact) from increasing the normally low-potential circuits to a dangerous loading. The wiring for lighting systems of buildings is designed for a maximum of 150 volts to ground. Let us assume that a street series circuit operating at 5,000 volts should fall across the service wires from the pole to your home. With no ground on the "neutral" of your secondary wiring, its potential would be raised from its normal low value to a maximum of 5,000 volts. Certainly something must happen; either a fire is started, or perhaps a member of your family may be killed. The effect of such danger has been observed when service thawing current reaches the house wiring. In these instances the "ground" has worked in reverse, but proves its safety value and the necessity of "breaking" the service line before electrical thawing is started. Now consider these same conditions to exist, except that now your "neutral" is properly grounded. When the high-potential circuit is now temporarily crossed with service, the high-potential currents are safely carried to ground, and no one in the home would realize the possible disaster that the ground connections have avoided.

When, What and Why Ground?

There is no doubt that a full study and discussion of the entire subject of grounding by the new functioning joint committee will prove well worth while. It is certainly to be hoped that there will result a greater care in the preparation and arrangement of ground connections between the electric and water systems, and that the volume of curent flow be intelligently regulated. We, the water utility interests, should not embarrass this effort by hasty demands to prohibit all grounding of water systems. As a matter of fact, we could not do so, even if thoughtless enough to demand such.

[Water works men have themselves found difficulty in effectively grounding pumping station motor circuits by any other method than an efficient connection to their own pressure mains leaving the station.—Ed.]

No wires used in lighting systems should have more than 150 volts to ground. The wires of power circuits, such as 220 or 440 volts, *should not be grounded.* All appliances, frames of motors, conduit, etc., in addition to the "neutrals" of lighting systems, should be carefully and effectively grounded. Inspect grounds frequently. The snuffing out of a life may be the penalty if you do not. Satisfactory operation is another, if secondary, reason for so doing.

PART 4—MOTORS

Alternating current motors are of two general types: the synchronous and induction. The main difference between these two types is that, while the synchronous motor can run only at a definite constant speed (synchronous speed), the induction motor must operate at a speed dependent upon the load applied, but never at synchronous speed. There are other important differences that, to better advantage, will be mentioned later.

Synchronous Type

At a given frequency the speed of a synchronous motor may be determined by the equation;

$$N = \frac{120f}{P} \quad \ldots\ldots\ldots (8)$$

in which N = revolutions of rotor per minute (RPM); f = frequency in cycles per second; P = number of poles.

Since the standard frequency is 60 cycles per second, equation 8 is generally expressed in the form:

$$N = \frac{7200}{P} \quad \ldots\ldots\ldots (9)$$

From this it is evident that the maximum speed for a 60 cycle motor is 7200/2 or 3600 RPM, and the speed, N, from equations 8 or 9 is known as the synchronous speed of the motor. This, for 60 cycle motors, is the constant 7200 divided by the number of poles; and, since the number of poles must be an even number, synchronous speeds become 3600, 1800, 1200, 900....RPM. One of the greatest limitations of the synchronous motor is that it cannot be built to operate at other than synchronous speeds, when oftentimes an intermediate speed is needed.

On the other hand, the fact that it runs at an exact speed is quite frequently its greatest asset. Electric clocks and timing devices depend upon this characteristic for their value and dependability as to accuracy. Pump drives, and mechanical devices of all types that require an exact and fixed speed, necessitate the use of the synchronous motor for this reason.

Another marked difference between the synchronous and induction motor is that the former requires salient magnetic poles, excited (magnetized) from a source of direct current; whereas, the induction motor has no such poles and requires no separate excitation. In fact, the standard squirrel-cage motor is well named, because its rotor is essentially nothing more than a circle of bars parallel to the shaft which are held in place and short-circuited by two metallic rings. Picture the revolving cage for the squirrel's exercise and you have it—thus, the name.

Unfavorable Characteristics

The necessity for this auxiliary direct current is indeed unfortunate, because direct current generators are difficult to maintain. Hence, greater skill and maintenance are required for synchronous than for induction motor operation. Then, too, the starting characteristics of the synchronous motor are rarely satisfactory. The starting torque (that is, the twist or pull) cannot approach that of the induction motor; frequently necessitating expensive and complicated methods of holding the load off the motor until it has reached full speed. Fortunately, centrifugal pumps may frequently be started under no-load without inconvenience, which renders this deficiency of the synchronous motor of no real importance.

Favorable Characteristics

On the favorable side of the ledger, the synchronous motor does possess the ability to operate with a "leading" power factor, contrasted to the rather decidedly "lagging" power factor of the standard induction motor. As has been stated previously, many power companies offer a lower rate to consumers whose requirements make permissible a desirable power factor. Where this is the case, the ability of the synchronous motor to operate at the "leading" power factor may have influence in the selection of the type of motor to be adopted.

From the above, it can be seen why, for water works and sewage treatment plants, the use of synchronous motors is frequently advised against. They are only to be considered when exact speed is essential or power costs may be lowered appreciably by the favorable power factor. Even then, the engineer will do well to be certain that savings in power bills will offset the increased operating difficulties that are certain to be realized in the use of synchronous motors.

Induction Type

The induction motor differs from the synchronous type in that it requires no separate excitation, and its ability to operate at a variable speed, as contrasted to the constant speed synchroncus motor.

At no load an induction motor will run almost up to its synchronous speed. It should be understood that while the induction motor has no salient poles, the stator is wound to produce two, four or any even number of poles, just as is the stator of a synchronous motor; hence it has a synchronous speed of 3600, 1800, 900 RPM, just as does the synchronous type.

As the load on an induction motor is increased, the speed gradually lessens until at full rated load the speed is reduced from two to four per cent of its synchronous speed. Thus a given motor may have a synchronous speed of 1200 RPM, a no load speed of 1199 RPM and a full load speed of only 1170 RPM. If the load is further increased, the "slip" (as the loss of speed is called) will increase until a definite value is reached, at which point the motor will come to a stop. This load is known as the "pull-out" load.

Favorable Characteristics

Standard induction motors have very favorable starting characteristics, requiring relatively a small starting current and producing 200 or more per cent of full load torque. They are the most rugged and reliable of all motors. But while they will successfully operate under most adverse conditions, reasonable care should be taken to keep the air ducts and windings free from lint and dirt. The oil in the bearings must be flushed and changed at least once each year.

Smaller and specially designed induction motors require no starting device, and may be started by applying normal full voltage. Larger motors require reduced voltage for starting, which is

usually obtained from auto-transformers, called starting compensators. Two coils, each on an iron core, are connected open-delta across the three-phase lines; a 40, 50 or 60 per cent tap is taken to the motors for starting. After the motor has started and reached a constant speed, the compensator is disconnected and full voltage goes to the motor.

Variable Speed Motors

The wound-rotor induction motor, for operating at variable speeds, is not so rugged as is the standard squirrel-cage type. It is more expensive and also usually less efficient. A misunderstanding of the speed characteristics of these motors has caused no end of trouble. We may gain a clear conception of the speed variation of the wound rotor, induction type motor if we think in terms of "slip." As stated above, the standard squirrel-cage motor "slip" varies from virtually nothing at no load to about 3 per cent at full load. With the wound rotor, external resistance may be added to the rotor circuit, the effort of which is to *increase* the slip. Hence, this motor will run at essentially *constant* speed at no load, regardless of the amount of external resistance introduced in the rotor circuit. But, as the load is applied, and the greater is the external resistance, the more rapidly will the speed drop off.

Practically, this means that if we desire to drive a centrifugal pump at a variable speed, in order to vary the head and quantity delivered, we must first learn from the pump manufacturer both the speed and the horse-power required by the pump for each value of head-quantity desired. This data is then furnished the manufacturer of the motor who will design the external rotor resistances so that the various controller positions will connect the correct resistance to cause the speed to be that needed for the pump to operate under the desired condition.

Since power is a product of speed and torque, it should be remembered that less horse-power output can be obtained from a motor operating at a reduced speed than at its normal full speed. The reduction in motor output is approximately proportional to the reduction in speed. This fact should be considered at the time of purchase in order to be certain that the motor will not be excessively heated when operating at any of the reduced speeds. The same resistors that serve for speed control are also used for starting, hence no compensator is required as is the case for some of the standard squirrel-cage types.

Motor Ratings

The rating of most electrical apparatus such as motors, transformers, etc., is based upon the temperature rise that will occur when the device is operated continuously under normal full load and normal voltage conditions. Many manufacturers recommend a limit of fifty-five degrees centigrade rise, while other base their estimates upon a rise of only forty degrees. After all, this simply means that with a given motor rated at 100 HP, at 40 degree rise would be rated at 125 HP at 55 degree rise. All things considered, it seems to be the consensus of opinion, and dictate of wisdom, that all important motors in water works and sewage treatment plants should be purchased for a guaranteed rise, not to exceed forty degrees centigrade.

RAPID EMERGENCY METHOD OF THAWING HYDRANTS*

By E. E. JACOBSON

Chief Engineer, Lexington Water Co., Lexington, Ky.

One of the many worries of the water works man during the cold winter months is the problem of fire hydrant maintenance and their operation when the thermometer drops below freezing.

Proper inspection and drainage of fire hydrants will eliminate most of the trouble but hydrants only a few days after inspection have been found to contain water in the barrel. As the weather turns cold the water in the barrel becomes ice and the hydrant will not operate. No doubt every water works superintendent in states that have cold winters has experienced frozen fire hydrants.

The method used in Lexington, Ky., for a number of years as an emergency method of thawing ice from hydrant barrels is by pouring concentrated sulphuric acid into the hydrant barrel. During the Fall each piece of apparatus of the Lexington Fire Department is supplied with a quart bottle of sulphuric acid (66% commercial). When the acid is used the Lexington Water Company is notified and another bottle is sent to the fire station. In the Spring of the year these bottles are collected and fresh acid is issued each Fall.

When answering an alarm and a hydrant is found to be frozen, the acid is poured into the barrel through the nozzle and a slight pressure put on the stem operating wrench. As soon as the heat produced by the acid drills a hole through the ice cake the hydrant is opened, flushing out the acid with the first gush of water.

In frozen hydrants we have found that the ice forms first above the valve and in most cases it is doubtful if the acid reaches the valve because the stem turns and the water is turned on as soon as the ice melts around the stem.

The average time for thawing hydrants with acid is about three minutes although this would depend upon the thickness of ice in the barrel of the hydrant, and might vary considerably from the above time if very thick.

The advantages from this method of thawing hydrants comprise the ease of handling the thawing material on the fire trucks, the small space necessary on the trucks, simple to use, inexpensive, and the rapidity of results. Hydrants in which acid was used have been taken apart and no ill effects to the hydrant parts could be found.

The effectiveness in the use of sulphuric acid for this purpose can be determined by the following letter from the Chief of the Lexington Fire Department:

Mr. E. E. Jacobson, Chief Engineer — April 11, 1936.
Lexington Water Company,
Lexington, Kentucky.

Dear Mr. Jacobson:

Relative to our conversation this morning, I am furnishing you with all the information that I have in regards to the use of sulphuric acid in thawing fire hydrants during extreme cold weather.

In case a hydrant is found to be frozen, one of the caps of the hydrant is removed and a quart of acid is dumped into the barrel of the hydrant. The suction hose is then replaced on the hydrant, and in the majority of the cases the hydrant is thawed out by the time the suction is replaced, and the hydrant is turned on. The water and acid is allowed to flush out through the pumper or the hose, and we have found that little or no damage is caused by this action, due to the fact that the acid is neutralized by water to such a degree that it is harmless to the pumper or the hose.

In some instances the acid is a little slow about thawing the hydrant, but in these cases it is usually in certain parts of the city, where the surface water seeps in the barrel of the hydrant, causing the hydrant to have more water than usual in the barrel, but as soon as these hydrants are found, your company has had them filled with alcohol, thereby eliminating this trouble.

You will notice that we say that we replace the suction or the hose to the hydrant before we turn on the water. This is done to prevent acid burns to members of the department and the hose and apparatus that is near the hydrant. The first spurt of acid and water from the hydrant would be dangerous to any thing that it touched, but by replacing the cap, the acid is diluted with the water to a point where it is practically harmless to any thing it might touch.

It has required from two to eight minutes to thaw a hydrant with acid, where it usually requires about ten minutes to thaw out a hydrant with a regular thawing device, old style thawing device.

A test was made at fire department headquarters today. A fifty pound block of ice was used and one quart of sulphuric acid was poured into a hole in the ice. Ten minutes later a hole was burned in the ice eight inches deep, six inches wide and ten inches long. Of course, this was a little longer than it would have been in a hydrant, due to the fact that acid will follow the stem of the hydrant and penetrate into the ice faster than it did during the test. We have found the use of sulphuric acid for thawing hydrants to be most satisfactory.

C. J. HENRY,
Chief, Lexington Fire Department.

*From WATER WORKS AND SEWERAGE, December, 1936.

THAWING FROZEN SERVICE PIPES

By REEVES J. NEWSOM*

Consulting Engr., New York, N. Y.

The most rapid and economical method of thawing has been by the use of electric current. The most commonly used scheme of electrical thawing has been to get the local power company to mount transformers on trucks and to connect to existing power lines in the streets. The cost of this method is apt to be greater than the use of other types of electrical equipment, but there is usually not time to get other equipment after the freeze-ups began. In outlying districts no power lines were available in some cases, and other methods had to be resorted to. Engine driven generator sets especially designed for the purpose were only occasionally available, but the modern electric welding outfit was found to have approximately the voltage and amperage range required for thawing services, and where these outfits were used for thawing mains two of them were generally used in parallel.

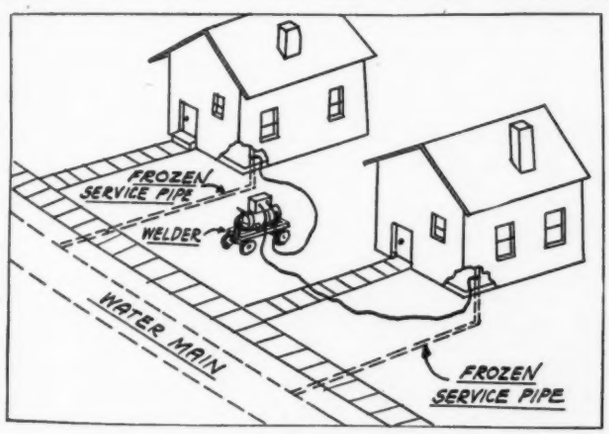
A third type of electrical equipment which was effective for short services, where connections could be made close together, was a small portable transformer with a capacity of about 150 amperes at 20 volts. On some systems a surprising number of services were successfully thawed with equipment of this type—the current being taken through the residence wiring outlets.

Where only a few frozen services were encountered or where the electricity was not available; or, where it was ineffective due to rubber gasketed couplings, new lead substitute joints in the intervening main pipe, or lack of capacity to thaw copper services, steam and hot water were used. One man can operate the steam outfits and do the thawing.

Steam is effectively used by generating it in a small portable boiler and feeding it under about 10 lbs. pressure through a ⅛-inch copper tube or 3/16-inch block-tin tubing. It is successful for only relatively short straight pipes where the steam jet can be advanced against the ice face as it melts. Where sharp bends are encountered and the tube cannot be advanced, the steam will not carry forward through the melted ice. Also, if the length of the service is too great the steam condenses in the tube before reaching the ice face and is not effective.

Hot water is, in general, more satisfactory than steam, though it requires two men to operate the equipment—one to push the tube into the pipe as the melting of the ice advances, and the other to operate the small force pump required. This method can be used on a longer service than the steam process and the hot water will carry farther beyond the end of the tubing when it meets an obstruction than does steam.

Small sections of 4-inch main about 75 ft. in length can be thawed by this method and if ⅜-inch iron pipe is substituted for the copper or tin tubing, the length that can be thawed can be approximately doubled. Where relatively new lead-substitute (compound) joints are encountered, preventing the use of electrical thawing, this becomes a valuable method of thawing larger mains also.



Sketch showing electric thawing equipment hook-up to thaw two services. One connection may be made to a fire plug, if convenient, when only one service is to be thawed. Before turning through the current the house piping is disconnected from the service line for safety.

Mobile Welding Generator Set Thawing Frozen Service Lines.

Time Required for Thawing

Experiences indicate that the time required for thawing services by all three methods varied through a wide range. Where equipment of adequate capacity was available for electrical thawing services were often thawed in from three to ten minutes and small mains in from one-half to two hours. Both hot water and steam thawing require a considerably longer time than this. However, in many instances, because of lack of experience and precedent, many jobs of thawing of both long services and mains were attempted without adequate equipment; and, as a result, two or three hours were often spent on a service and as long as ten or more hours on a main.

Cost of Thawing Operations

The cost of electric thawing was made up of many combinations of charges. In cases where hook-ups were arranged with the local power company, the charge was sometimes a stated amount per service or an hourly charge for the equipment, with or without a current charge. Welding outfits were supplied both on a per service basis and an hourly charge for men and equipment. The cost commonly varied between $2.50 and $7.50 per service for electric thawing, and the use of hot water and steam applications also came within this range. A common charge for welding outfits was $4.00 per hour, although it varied from $2.50 to $7.50 per hour.

Difficulties Encountered

One of the principal difficulties encountered in thawing by electricity has been the occasional inability to get a closed circuit through the pipe or main that will carry sufficient current to produce the required heat. The most common cause of this type of trouble is the presence of lead substitute joints in the section of main between the frozen service and whatever point is used for the circuit making connection. The weight of evidence from past experience appears to show that new lead substitute joints definitely will not carry sufficient current for thawing. Depending somewhat upon the character of the water, joints of this type in about five years will have formed, by corrosion of the iron in the bell and the material itself, a contact that will carry the current. This contact is somewhat fragile, however, and if too large an amperage is forced through it, it may burn through and break the circuit or create arcing and damage, after which other means than electricity will have to be used. To avoid this, it is necessary to keep the amperage below 200, or probably 150, and keep the current on for the extra time required. Rubber bushed repair couplings or joints are another reason for being unable to get a closed electric circuit, and, except in rare instances, time does not seem to produce a satisfactory current

*President of the American Water Works Association; former President, Community Water Service Co.

One of the Mobile Welding and Thawing Units—Ottawa, Canada, Water Department.

carrying contact unless much higher voltage is available than is needed for ordinary thawing work.

Failure to ascertain that there is no other path for the current to take than through the service line may lead to failure in thawing, even though the ammeter indicates that the proper amount of current is flowing. In some cases the current has taken a path through the house wiring and has heated the small wires (and BX cable carrying them) hot enough to set the house afire. It is not sufficient merely to detach the ground wire that is customarily found near the cellar wall, because other ground connections may be present elsewhere. *A complete disconnection of the piping system from the service line, by removal of a fitting or the meter, is the only safe course.*

Necessary Consideration in Successful Thawing

The thawing of services and mains by the use of electric current will be more uniformly successful if water works operators will bear in mind the fundamental characteristics of current flow and energy transference. Amperage is the measure of quantity of current flowing and is the most important element to consider because on the one hand the heating effect desired is principally dependent upon the flow of a sufficient number of amperes of current and, on the other hand, damage to joints and pipe is caused by too great an amperage. Voltage is the measure of electric pressure which is driving the current through the pipe. Voltage is therefore important only because of the amperage which it will force through the resistance of the pipe and joints. Ohms are a measure of resistance—i.e.—electric friction. The relation between the three is expressed as Voltage equals Amperage times Ohms. Thus, the greater the resistance, the greater must be the electric pressure (voltage) to force through a given amount of current.

Resistance, therefore, if it be in the joints, is a detriment to current flow and to the thawing. But the resistance of the material of the pipe to be thawed is useful in thawing, for ultimately it is the heat, produced by the force of the current, that melts the ice, and the greater the resistance, the greater the heat produced by a given amount of current forced through.

The transference of electric energy into heat in a conductor takes place according to a law first stated by James Joule, an English physicist. According to this law, the heat produced is directly proportional to the resistance of the conductor, the square of the amount of current and time the current is flowing. Thus it will be seen that a material which is a poor conductor and offers greater resistance to current flow will get hotter than one which is a good conductor. Also, a relatively small increase in amperage will greatly increase the heat produced as the variation is as the square of the amperage increment.

It would appear from this law that any difficult job of thawing could be done by merely continuing the current flow for a long period, and to a limited extent this is true, but it must be remembered that the heat produced in the pipe is immediately dissipated by the ice inside and the cold soil on the outside. Therefore, for any rate of heat production there is a point reached where it is dissipated as fast as produced; and, if in a reasonable time the pipe line is not thawad it is safe to conclude that too much of the heat is being lost through the soil and mere continuance of this condition for a longer time will not bring success. More heat must be provided and since the resistance of the pipe cannot be controlled, increased current flow (amperage) is needed. To secure this additional flow of amperes an increase in the electrical pressure (voltage) is necessary.

As a result of this law of Joule's, it can be seen that a copper pipe, being a good conductor, can only be heated by passing a considerable amperage through it and for a longer time than in the case of other materials (such as iron) which are not such good conductors. Comparing the resistance of the various metals used for water pipes, in order, copper is the least resistant. Considering copper as 1, steel is 7, wrought iron is 9, lead is 12, and cast iron is 73. Since copper has 1/7th to 1/9th the resistance of steel and iron and 1/12th that of lead, it is necessary to put through at least twice the amperage for approximately twice as long a time in order to thaw a length of copper service pipe as is required for the same length of steel pipe.

Experience

Experience has shown that from 200 to 400 amperes (varying with the diameter) will thaw iron, steel or lead services in from three to ten minutes. Depending upon the character of the connections, the type of joints in the mains and other elements of resistance, the voltage necessary to force such a current flow through the circuit will vary from 10 to about 60 volts. To thaw mains, amperages of from 400 to 700 are likely to be required at times. In view of the larger area of metal in these pipes it is fortunate that cast-iron has high resistance to current flow, else it would be impossible to produce sufficient heat with any practical portable electrical apparatus.

To produce a current of 400 amperes at 60 volts requires about a 25 k. w. generator, although one with a capacity of 30 k. w. is better. The gasoline engine driving it should have a rated capacity of at least 50 per cent more in order to sustain the output for several hours in case difficult main pipe thawing is encountered.

If current is taken from the 2300 volt lines of the local power utility and is stepped down to 110 volts, the transformers should have at least a total of 75 KVA capacity if mains are to be thawed, because it is occasionally necessary to use higher amperages than the average stated and also to maintain the current flow for several hours. A 25 KVA transformer is usually ample, however, for the thawing of services. It has been observed that AC current is more effective than DC in thawing because the vibration set up by the former is of material aid. The necessary small amount of melting near the pipe surface takes place with less actual temperature rise in the pipe.

Some Relationships Between Current Flow and Heat Production

1—*Kilowatt*
= 56.92 B.T.U. per min.
= 1.34 horse-power.

1—*Horse Power*
= 42.44 B.T.U. per min.
= 0.7457 KW.

1—*Horse Power/Hour*
= 2,547 B.T.U.
= 0.7457 KW.H.

1—*B.T.U. per Min.*
= 0.01757 KW.
=0.02356 H.P.

1—*Kilowatt/Hour*
= 3.415 B.T.U.
= 80.46 H.P.

REGULATING WATER PIPING WITHIN BUILDINGS*

By STEPHEN H. TAYLOR

Superintendent, Water Department, New Bedford, Mass.

It is the opinion of the writer that sufficient attention has not been given in the past by water works officials to water piping and fixtures inside of the taker's premises.

Until last year, we in New Bedford have felt that when we assured ourselves that the service pipe to and including the meter were of proper material and properly installed our responsibility and jurisdiction ended; and, what was installed inside of that point was wholly the affair of the owner and his plumber. I think it is safe to say that most water works officials in this country have taken the same attitude.

In consequence, we find in many cases that faulty workmanship has been a result and inferior materials have been installed. In addition, sanitary fixtures are often of a design and so installed as to unwittingly introduce a danger to health through pollution of the water supply within buildings by siphonage or gravity backflow of polluted water from bowls and other fixtures to the water supply piping. Speculative and boom building has resulted in many buildings being piped with cheap materials and fixtures, installed frequently by incompetent workmen.

It is a well known fact that the surface water supply of New Bedford is rather active and quickly fills wrought iron and steel pipes with rust and tubercles. This condition exists also in many other communities. In spite of such knowledge, many buildings have been piped with this type of material, with the result that after comparatively few years, water cannot be drawn through more than one fixture at a time and that one delivers only a weak supply. Services installed by the Water Department in New Bedford are of lead, in sizes up to 1 inch; and, copper or cast iron is employed for the larger sizes. In most cases we have installed the service up to the meter, which is usually located in the cellar of the building.

When complaints of poor flow come to us we clear the tap and service line, if necessary, and prove that the supply is ample up to the meter and that the trouble is caused by rust choking of the steel piping inside the building. This means many unnecessary visits and explanations; which takes considerable time of our employes. When the owner finds that his only remedy for the trouble is to repipe the entire building, to say that he is somewhat disturbed, is stating the case mildly.

We have also found that modern fixtures frequently of such a design that polluted water from them can flow back into the water supply pipes either by gravity or siphoning in case the pressure is reduced by heavy draught on the lower floor of buildings, or wherever the water is shut off in either the building or in the street.

Water Board Drafts Regulations

In an effort to improve these conditions the Water Board adopted a set of rules and regulations, which became effective June 1, 1935, governing the installation of house piping, which we feel will benefit the water department—but, more especially the public.

The city ordinances places the supervision of hot water tanks and water heaters under the jurisdiction of the City Board of Health. That department works in cooperation with our department regarding this equipment and has established rules which require that such equipment be installed in a manner which will be safe and prevent forcing hot water back to damage meters.

The new regulations follow.

[Note.—At this point the author outlined those parts of the regulations which embrace the principal requirements pertaining to "Inside Piping and Fixtures." Believing that our readers may prefer to have before them the completed set of regulations, these are reproduced below (in full) just as they appear in the neat little brown booklet (3¾ x 6 in.) which is distributed by the New Bedford Water Department.—Editor.]

New Bedford Water Board Regulations Governing Water Service Supply Piping and Fixtures† June 1, 1935

(See separate pamphlet for sprinkler piping regulations)

Section I. Every water-taker shall pay the established rates for water supplied within the time and at the place specified upon bills rendered; shall at his own expense, keep the service pipes within his premises in good order and repair and protected from the frost; shall not allow the water to run to waste; shall not make any change in the service pipe between city main and meter, unless sanctioned so to do by the superintendent; shall not conceal the purpose for which water is used; shall allow the superintendent, registrar and persons authorized by them, or by the board to enter the premises supplied with water to examine the pipes and fixtures and ascertain the quantity of water used and manner of use, and shall indemnify the city for all damages it may sustain or be required to pay, in consequence of any injury resulting from any violation of these regulations by the water taker.

Section II. All applications for service supplies must be made by the owner of property at the office of the registrar in the form prescribed, stating the various uses to which the water is to be applied.

Section III. SERVICE FROM STREET—In every case the installation of the service pipe from the street main to the end of pipe where taker's stop with waste is installed by the plumber shall be made by the New Bedford Water Department and the charge to the owner shall be as specified in regulation adopted by the Water Board February 6, 1924, viz.:

For installing one service to each property from the main pipe to street line as follows:

For ⅝ in. service	$31.00
For ¾ in. service	32.00
For 1 in. service	39.00

In cases where permanent pavement is disturbed, the owner is also required to pay for replacing the same.

For secondary services, temporary services or for services larger than one inch in size, the entire cost of installation, including cost of re-surfacing permanent street pavement.

For all services on private property, the owner shall pay the entire cost of such work.

Section IV. Each service shall be provided with a satisfactory stop and waste cock with coupling (this stop shall be round way and of the same size as the service pipe) to be located always just within the basement wall, at the point where the service pipe enters, and the pipes within the building must be so arranged that the water can be drawn from them whenever there is danger of freezing. The department will not be liable for any damage resulting from a failure to observe this important rule.

Section V. No water-taker shall be entitled to any damages nor will any portion of a payment be refunded for any sudden stoppage of the city supply occasioned by an accident or otherwise, nor for any stoppage for the purpose of making extensions, alterations or repairs. In such an event the water-takers must guard themselves against the collapse of boilers and other injuries liable to result from stoppage of the water supply.

Section VI. No cross connections between the City supply and any other supply which is not approved as potable by the State Dept. of Public Health shall be permitted except those which are properly protected by double check valves of an approved type. Said check valves shall be approved by the Water Board and shall be regularly inspected at the expense of the owner of the property by a representative of the Water Department at such intervals as the Water Board shall determine.

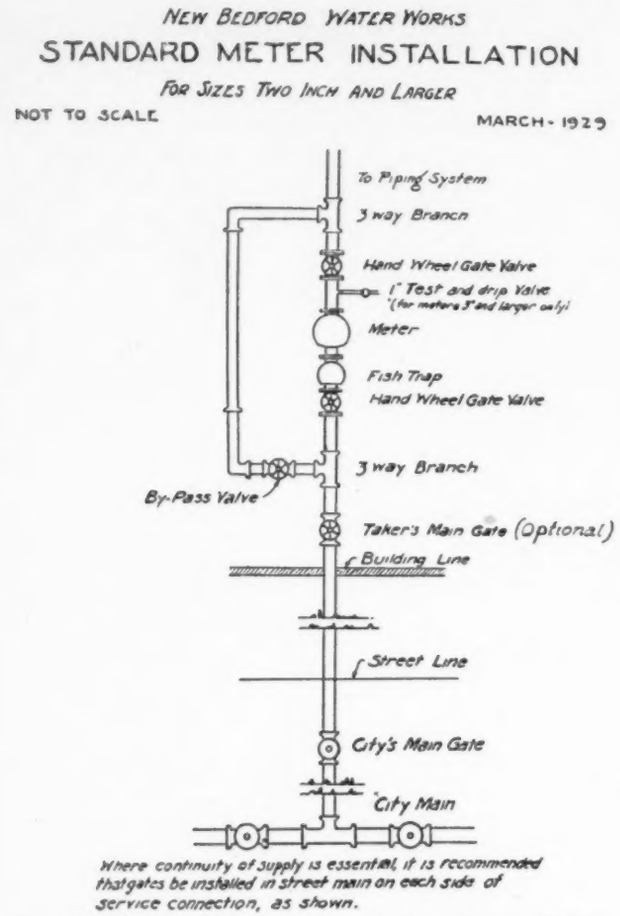
Section VII. METER REGULATIONS.

a. One meter of standard type and of same size as the supply pipe must be installed upon each service connection. It may be located between the curb stop and building or within building. If within building, it must be placed at a point adjacent to shut off, where pipe enters through foundation wall. If outside the building, it shall be installed in a satisfactory box or pit not less than 3 ft. x 4 ft. x 4 ft. deep. All meters 2 inches or larger shall be equipped with a by-pass capable of supplying the premises when the meter is removed for repairs or test. This by-pass valve to be kept sealed shut except when meter is out. (See Sketch.)

b. In all cases where one service connection supplies two or more separate consumers, or a block occupied by divers parties, only one meter will be used and the water rent as registered by said meter shall be charged to and payable by the owner of said premises or building. If additional meters are desired to ascertain sub-division or such supplies, they will be

*From Water Works and Sewerage.

†Regulations pertaining to inside piping and fixtures begin with Section VIII.


NEW BEDFORD WATER WORKS
STANDARD METER INSTALLATION
FOR SIZES TWO INCH AND LARGER
NOT TO SCALE
MARCH - 1929
To Piping System
3 way Branch
Hand Wheel Gate Valve
1" Test and drip Valve
(for meters 3" and larger only)
Meter
Fish Trap
Hand Wheel Gate Valve
3 way Branch
By-Pass Valve
Taker's Main Gate (Optional)
Building Line
Street Line
City's Main Gate
City Main
Where continuity of supply is essential, it is recommended that gates be installed in street main on each side of service connection, as shown.

Standard Meter Installation, New Bedford Water Works.

furnished at the expense of the applicant, who must assume all responsibility of reading and maintaining same.

c. Owners of property will be given option of either purchasing a meter outright and paying for its installation, or of having city furnish and install same and paying an annual rental therefor.

d. The property owner must keep the meter within his premises easily accessible for reading at all times. The city will include all repairs due to ordinary wear in its rental charge, but in all such cases, the owner will be held responsible for proper protection of the meter from all damage which may occur due to freezing or from hot water backing from overheated house boilers or other causes. Property owners will be assessed the cost of repairs of every nature necessary to properly maintain the meter owned by them. In case payment of such charges is not made upon demand, the water will be shut off from the premises supplied, and will not be renewed until after such charges, including the additional sum of one dollar, to cover expenses of shutting off and letting on the water, shall have been paid.

e. The owner of property shall pay at the established meter rate for amount registered, whether used or wasted. The water department will not assume any responsibility for use of water within metered premises.

f. Should a meter fail to register for any cause, the quantity shall be determined and the charge made based on average amount registered by meter when in order.

g. After a meter has been installed, it will not be removed for purpose of rating the premises supplied on any other basis of water charged.

h. No meter shall be discontinued from the pipe, moved or disturbed, without permission from the water registrar, who will send a properly authorized person to attend to any change needed.

i. If a house becomes unoccupied, the owner or agent may have the water shut off and the meter removed during the period of non-occupancy by making a request therefor to the water department, and paying one dollar to cover expenses.

Section VIII. PLANS TO BE APPROVED—Plans of proposed new installations, extensions or alteration of existing systems, showing proposed sizes and materials, must be filed with the Water Board, and approved by said Board or its designated representative before starting work.

Section IX. INSIDE PIPING—All inside installations shall be made under the direction of a registered Master Plumber, except in manufacturing plants or other plants where competent pipers are regularly employed. Connections to supply water heaters, hot water storage tanks, heating and ventilating apparatus, cooling systems and power plant equipment and apparatus may be made by competent employes of persons regularly engaged in the business of installing such apparatus, subject to the inspection and approval of the Water Board. Each holder of a Master Plumber's Certificate of License shall register his name and business address with the Water Board on or before the first day of May in each year. Notice of any change in the place of business shall be given immediately to said Water Board.

Section X. INSPECTION AND TEST—On completion of the installation it shall be inspected and approved by the designated inspector of the Water Board before the water supply will be turned on to the premises. It shall be tested in the presence of the inspector at city water pressure.

Section XI. KIND OF PIPE—All water supply pipes and fittings, shall be of lead, brass, copper or other non-ferrous metal or composition, except in the case of pipes four inches or more in diameter, in which case, cast iron pipe properly coated and lined with material approved by the Water Board may be used.

In order that piping shall be sufficiently strong to withstand City pressure with a reasonable allowance for corrosion all pipes must comply with the following minimum specifications.

LEAD PIPE:

All lead pipe for water service shall be made from soft virgin pig lead without any admixture of scrap lead or any other material and shall weigh not less than

For	½ in. pipes	3	pounds per foot
For	⅝ in. pipes	3½	pounds per foot
For	¾ in. pipes	4½	pounds per foot
For	1 in. pipes	6	pounds per foot
For	1¼ in. pipes	7¾	pounds per foot
For	1½ in. pipes	11¼	pounds per foot
For	2 in. pipes	19½	pounds per foot

BRASS PIPE:

All brass pipe used for water supply piping shall conform with the Standard Specifications of the American Society for Testing Materials for "Brass Pipe, Standard Sizes" Serial Designation B43-23, with the exception of Paragraph 4 thereof. In place of the said Paragraph 4, the brass shall conform to the following requirements as to chemical composition:

Copper, minimum	59.00%
Lead, maximum	0.50%
Iron, maximum	0.07%
Zinc, or Zinc and Tin	Remainder

This change admits use of so-called "Admiralty" and "Red" brasses.

COPPER PIPE:

All copper pipe used for water supply piping shall conform with the Standard Specifications of the American Society for Testing Materials for "Copper Pipe, Standard Sizes," Serial Designation B42-23.

COPPER TUBING:

All copper service tubing used for underground piping shall conform with the Standard Specifications of the American Society for Testing Materials for Copper Tubing, Government Type K, Serial Designation B88-33. For interior piping copper tubing, Government Type L, is allowable.

Fittings for use with brass or copper pipes shall be of material and strength corresponding with the pipe used. All installations shall be made in a thorough and workmanlike manner satisfactory to the New Bedford Water Board.

Pipes which are to be concealed in partitions or otherwise shall be tested as specified in Section X before being concealed.

No pipes which have previously been used for other purposes shall be used for distributing water.

Section XII. PROTECTION—All concealed water pipes, storage tanks, flushing cisterns, and all exposed pipes or tanks subject to freezing temperatures shall be efficiently protected against freezing.

Section XIII. DISTRIBUTION—The water supply shall be distributed through a piping system entirely independent of any piping system conveying another water supply.

Section XIV. WATER SERVICE—The water service pipe of any building shall be of sufficient size to permit a continuous ample flow of water to all fixtures on all floors at a given time.

Section XV. SUPPLY TO FIXTURES—All plumbing fixtures shall be provided with a sufficient supply of water for flushing to keep them in a sanitary condition and shall be ad-

justed to prevent waste of water. The water from water closet and urinal flush tanks shall be used for no other purpose.

The bottom of flush tanks for water closets or urinals shall be above the overflow level of the fixture when drain is obstructed.

All flushometer valves for water closets shall be equipped with a vacuum breaker of a type approved by the Water Board.

The supply pipe for each tenement or bathroom shall be not less than ½" inside diameter and connect to the main supply pipe, which shall be not less than the size of the main service. The main service shall be carried full size to the point where the last branch is taken off in the basement.

Accessible shutoffs with waste shall be provided in the basement which shall separately control the water supply for each tenement and for each hot water tank.

Section XVI. SIZE OF PIPES—The minimum size of water-service pipes from main to the dwelling shall be five-eighths inch, and to fixtures as follows:

Sill Cocks	½ in.
Hot Water Boilers	½ in.
Laundry Traps	½ in.
Sinks	½ in.
Lavoratories	⅜ in.
Bath Tubs	½ in.
Water Closet Tanks	⅜ in.
Flushometer Valves for Water Closets	1 in.
Flushometer Valves for Urinals	½ in.

[Note: A copy of the application form, for Water Department approval of piping and fixture installations, may probably be had upon request to the author of this article—*Editor.*]

Some Results

It is interesting to note that in spite of the fact that no new building has been going on in New Bedford during the 8½ months since these rules became effective about 700 permits for alterations and replacements have been issued.

Two outstanding cases of potential pollution from back syphoning have recently come to the attention of our inspector. One was in a large High School; the other in a department store of importance. These cases and many others show the need of constant vigilance on the part of someone, and we in New Bedford have decided that the Water Department should assume this responsibility as there is a possibility that pollution from such sources may even get back into our mains by siphonage or gravity when it becomes necessary to shut off the street mains.

The inspection has been placed in the hands of a Master Plumber of long experience who has the respect and confidence of other master plumbers. He is a full time employee of the Water Board and has the complete cooperation of the plumbing inspector of the City Board of Health.

The new regulations have been in effect since June 1st, 1935, and the results have been very satisfactory. The master plumbers cooperate very well with us as it protects them against unfair competition of unlicensed men and inferior materials. The public gains by being assured of proper supply and approved water fixtures. The department gains by being relieved of many complaints which come about as the result of improper materials or workmanship.

As far as the writer knows, very few communities have made rules regulating water service piping and fixtures inside of buildings. No matter how complete the main distribution system and service connection may be, the consumer will not get the supply he is entitled to at his fixtures or the protection against pollution within his own property unless someone sees to it that proper interior piping and fixtures are installed in an approved manner.

Our City Solicitor has ruled that the supervision of the entire water supply (except water heaters and hot water tanks), up to and including proper fixtures, is within the jurisdiction of the Water Department.

Representative Water Rates

That where water is the dearest it has been made available at such comparative low cost to consumers is a situation stressed in its publicity releases to consumers by Los Angeles' Department of Water and Power. What its Official Bulletin "Water and Power" had to say to Los Angeles water takers is of interest.

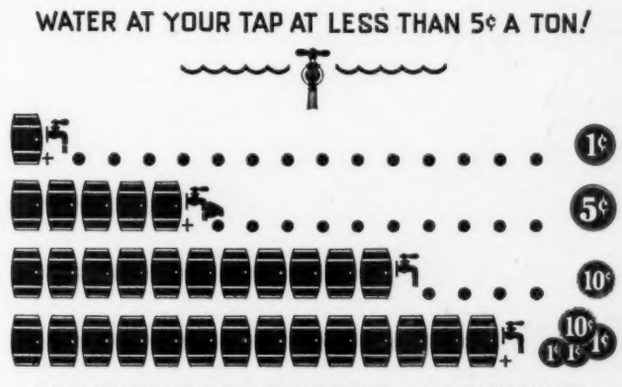
"Los Angeles consumers pay the low rate of 13 cents for 100 cu. ft. (750 gallons) of pure water brought in from mountain streams 250 miles distant. For the same amount of water the average charge in 183 of the larger cities in the United States is 18 cents."

The following rates charged by representative cities are cited in comparison:

San Francisco	28 cents	Youngstown, O.	20 cents
Pittsburgh, Pa.	25 cents	Miami, Fla.	19 cents
Indianapolis, Ind.	22 cents	Boston, Mass.	15.4 cents
Des Moines, Ia.	22 cents	St. Louis, Mo.	15 cents

Los Angeles ..... 13 cents

Any municipality which can show a rate below the 18 cents per 100 cu. ft. average in 183 representative American municipalities would do well to utilize the figures quoted, release the "story" to the local press and distribute reprints of this "news" with its water bills.



[*The above has been used by the Los Angeles Water Bureau to stress the cheapness of water at* 11 *barrels for a dime and no haulage to pay. More recently, however, Los Angeles rates have been raised somewhat to finance betterments. The picturization of* 5 *barrels of pure water for the cost of a poor cup of tea is the impressive part to the layman. Think of it!*—Ed.]

AIR CONDITIONING IN RELATION TO WATER CONSUMPTION

By LOGAN L. LEWIS*

Newark, N. J.

While it may be true that air conditioning has but recently become of peculiar but important interest to water works authorities, it is by no means a novelty. The industry is some thirty years old. During the first twenty years of its life, application was limited almost entirely to industrial plants and, hence, few people knew of it. About ten years ago its application began to spread rapidly to theaters, department stores, restaurants and other buildings in which the public gather. This second phase of development brought improvements in equipment, made price reductions possible, and greatly broadened the market.

From an air conditioning point of view, every human being in Jones' store is a heater, giving off heat in both its sensible and latent form, or, with freedom of description, as dry and moist heat. Every light, every electrical device, every coffee urn is a heater. The rays of the sun heat the building structure where they strike it, and heat also flows in through it, because a lower temperature is maintained inside the structure. Therefore his system must remove heat and moisture when the weather is warm and add heat and moisture when the weather is cold.

For effectively removing heat, we must have a refrigerating machine of which there are many types, all of which must be provided with means for removing the effluent heat. This effluent heat usually is carried away wholly or partly by the water furnished, and requirements may be great. In winter requirements for water are minute. Thus, demand for water is a seasonal one and proportional to the quantity of heat which must be removed.

A simple way to get rid of this heat is to buy water from the water utility and pass it through his condenser to the sewer. If this were the only way to do it, water departments might well be concerned by the demand. But, in certain cities, the cost of water was high and the manufacturers of air conditioning and refrigerating equipment sought means of reducing water costs. And, so, economic forces began to stimulate the development of equipment which would reduce sales resistance by reducing the need for water where the rates were high, or where the threat of water shortage might restrict its use. This has borne fruit, so that there is available water conserving equipment which may, in some localities, reduce sales that water works managers would like to make. However, in other localities this improvement may prove a desideratum in reducing excessive demands.

The Economy of the Cooling Tower

The first stage of this development was the cooling tower—that slatted structure which you will recognize as the architectural abortion you have seen upon the roof of some local ice plant. This cooling tower is a means of heat disposal. The water passing through it is recirculated, being pumped through the condenser where it receives heat, and then through the cooling spray tower where it gives off this heat to the air. Some of the water is carried away by the wind, some of it is lost by evaporation, and that which is lost must be replenished from the source of water supply. This loss is quite small, so that the use of this cooling tower for heat disposal has cut the demand for water to less than 10 per cent of what it would otherwise be.

To be fair to the cooling tower, it must be said that much has been done to improve its appearance. The second stage was the development of the evaporative condenser, in which the functions of the condenser and the cooling tower have been combined. The features of water conservation have also been further improved thereby and the space occupied by equipment greatly reduced. This piece of equipment may be placed upon the roof of a building and appear as a small rectangle, or, if it is feasible to lead air to and from it through ducts, it may be tucked away in one corner of the machinery room.

Since there is no windage loss from the evaporative condenser, it requires less than 5 per cent of the water which you would otherwise furnish. Both the tower and the evaporative condenser are instruments for the conservation of water and are fully developed practically and commercially.

*Chief Engineer, Carrier Corpn., Newark, N. J.

Water Demands of Modern Equipment

What is the magnitude of this demand for water going to be and what will be its characteristics? Let us examine the demands for water of the several types of prevalent installations of air conditioning, which are given in Table I which accompanies this discussion.

B.t.u., or thermal units, per person will vary somewhat for each installation, but limits of variation are well known. Hours of operation per season can readily be set for maintenance of the desired conditions. Load factors, or the relation of average load to maximum load, are based on experience. Gallons of both maximum and average demand must be based on an average water temperature and an average balance between water and power. Hence, Table I is necessarily composed of figures which are admittedly controversial as to the interpretation of experience, for multifarious economic forces press in some localities for excessive use of water and in others for conservation thereof.

For a given electric power rate, cold water may throw the balance in favor of heat disposal entirely by water—warm water may do the opposite. Low power rates may favor conservation of water—high power rates, the opposite. A combination of high's of water temperature and power cost operate strongly in favor of heat disposal by evaporation.

The complexity of these economic forces becomes apparent when it is realized that power for air conditioning may cost from less than 1 cent per k.w.h. to more than 3 cents; that water may be purchased at rates varying from 45 cents per 1,000 cu. ft. up to $2.85—perhaps higher; that the temperature of the water coming from mains may range in summer from 56 to 85 degrees F.; and that pocketbook limitations to available capital may enforce the purchase of equipment which, being of low capacity, is above average in demand for water or power, or both.

But, let's continue our examination of the averages arrived at in Table I as they are carried forward in Table II. Three important facts become obvious.

First, that the demand for water is seasonal. It is high in summer and, as previously stated, insignificant in winter. An 120-day cooling season is typical of New York. In the South, it may exceed 150 days.

Second, that economic forces and restrictive regulations, such as are now applied in New York, did, in 1935, lead to extensive purchase of evaporative heat disposal systems. As a result, water consumption was cut by 60 per cent.

Third, that within the cooling season, the peak demand is far above average consumption.

Two figures in Table II are of such importance that they

TABLE I

DEMANDS OF SEVERAL TYPES OF AIR CONDITIONING INSTALLATIONS FOR WATER

VALUES ARE PER PERSON
SEASON OF 120 DAYS
WATER COOLED CONDENSERS

	BTU/HR.	MAX. DEMAND GAL./HR.	HRS. OPERATION PER SEASON	GAL./SEASON AT MAX. DEMAND RATE	LOAD FACTOR PERCENT	PROBABLE USE GAL./SEASON
RESIDENCE	4,000	40	2,900	160,000	30	48,000
TRAIN	1,400	14	1,200	16,800	50	8,400
OFFICE	4,700	47	1,200	56,400	40	22,500
LUNCH ROOM	1,600	16	900	14,400	50	7,200
RESTAURANT	2,000	20	1,200	24,000	60	14,500
DRUG STORE	2,000	20	1,800	36,000	60	21,500
THEATRE	1,000	10	1,500	15,000	30	4,500
DEP'T. STORE	1,600	16	1,200	19,200	60	11,500
AVERAGE	2,300			42,500		17,200

TABLE II

AIR CONDITIONING REQUIREMENTS FOR WATER

GAL./PERSON

THE FOLLOWING ARE "COLD AVERAGES", ADMITTEDLY CONTROVERSIAL AS TO THE INTERPRETATION OF EXPERIENCE.

	NO EVAPORATIVE CONDENSERS OR COOLING TOWERS USED.		BASED ON USE OF EVAPORATIVE CONDENSERS OR COOLING TOWERS ON 60% OF INSTALLATIONS. 1935 EXPERIENCE	
	IF MAX. DEMAND IS SUSTAINED.	PROBABLE USE	IF MAX. DEMAND IS SUSTAINED.	PROBABLE USE
PER SEASON OF 120 DAYS	42,500	17,200	17,000	7,000
PER DAY FOR SEASON OF 120 DAYS	350	140	(140)	60
PER DAY FOR YEAR 365 DAYS	120	50	50	(20)

have been encircled. Note carefully that they are *not* the *per capita* consumption that water works men are accustomed to using.

Air-conditioning-wise, they will become per capita consumption if and when air conditioning installed and operated for the entire population served by the water system. This does not mean that every building in a city must be completely conditioned. It does mean that the sum total of the number of people upon which the capacity guarantees of the systems are based has reached the sum total of population. In still other words, it means that there will exist an air conditioned spot for each and every person in a city, and no more.

If air conditioning sales double every four years, at some time in a period between 1945 and 1950 the per capita demand upon water systems for modern air conditioning may become:

(1) Maximum rate—35 gallons per day per capita.

(2) Average rate—5 gallons per day per capita.

Provided the present practice of using evaporative condensers and cooling towers is maintained. But if evaporative condensers and cooling towers be used exclusively from now on and be substituted for existing condensers, now wasting water, then these two rates would be cut to:

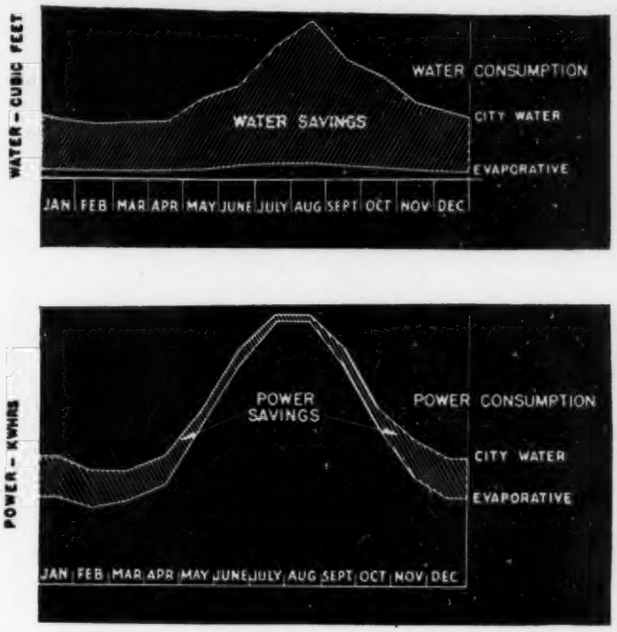
(1-a) Maximum rate—23 gallons per day per capita.

(2-a) Average rate—3 gallons per day per capita.

Water works managers may be divided into two groups:

1. Those to whom air conditioning offers an opportunity to sell more of their product.

2. Those to whom any increased demand will present a serious problem, and those who may now be unable to meet existing demands if rainfall is below average.



Water Conservation Made Possible by Use of Modern Evaporation Condensers

My conclusions are:

(a) With respect to Group 1: The maximum demand of 23 to 35 gallons per capita per day may overtax existing water works pumping equipment or, if not that, the capacity of the mains at certain focal points.

(b) With respect to Group 2: Their inability to assure a continuity of supply, either at present rates of consumption, or at present rates plus 3 to 5 gallons per capita per year average, or to pump and distribute as in (a), should be faced squarely as the facts stand, and proper restrictive measures instituted.

(c) Generally: That the number and complexity of factors are such that the problem will not yield except to analysis of a specific survey.

(d) That it is to our common interest to know and face the facts; and, worth our mutual effort to obtain them.

REMOVING WATER FROM MAINS WITH COMPRESSED AIR*

Eliminates Pumping, Wet Trench, Loss of Time

By ROGER W. ESTEY[1] and NELSON BOARDMAN[2]

Danvers Water Works, Danvers, Mass.

Often in the repairing of mains or replacements of old pipe lines, the question of time is of paramount importance. The removal of water from these mains is many times a lengthy and most disagreeable part of the entire procedure. It often takes as much time to eliminate the water as it does for the connecting in of the new material.

Of course, today we have gasoline-driven diaphragm and centrifugal pumps that remove the water much faster than the old-fashioned hand methods. But, even with this more efficient and faster way of removing the water, it does not overcome the objectionable features, of water gushing out when the pipe is being cut in the trench. Sometimes where there are no blow-offs to remove the water entirely or take off some of the pressure that may be caused by the irregular contour of the ground, removing a piece of pipe from the line is a wet and disagreeable job. Besides this, all of the men have to be equipped with boots.

Another worry that goes along with such a job is the attention that has to be given to the soil conditions. If the nature of the soil is sandy and gravelly, any great amount of water in the trench may cause a slight washing or wearing away of the bank, causing either one or both banks to cave in. This is a very important part of the work to watch, because in many instances it is not possible to shut the water off any length of time without causing great inconvenience to the customers, and then there is always the fire hazard which must be given consideration. Any caving-in of the banks therefore naturally increases the time to complete the work. When the soil is clayey, water in the trench makes a nasty mess to work in, and it is nearly impossible to keep the pipe and fittings clean.

There have been many times when we have thought over the above undesirable conditions and wondered if there wasn't some way whereby this could be overcome. In several places we cut in blow-off lines, but since there are so many places requiring blow-off lines, this method seems both impractical and too costly.

Compressed Air Considered

Three things came to our attention that caused us to give consideration to the use of compressed air to remove water from the mains. One of us stopped in at a local garage, and while there a customer came in and asked for a gallon of denatured alcohol. The proprietor took the container and went over to a barrel and placed the container on top of the barrel, under a riser pipe, and opened the faucet. Much to our amazement, the alcohol came out so fast it was only a moment or two until the container was filled. After the transaction had been completed we inquired, "How is it that you get that pressure from the alcohol barrel?" He informed us that every now and then he would take the hose line used to pump up tires and put it on to another connection, on top of the barrel, and build up an air pressure in the barrel. When opening the faucet the alcohol would gush out. That gave me an idea.

[1]Superintendent and [2]Assistant Superintendent.
*From WATER WORKS AND SEWERAGE, June, 1936.

Compressor Connected to Hydrant

Removal of Water from a 12-In. Main

At about the same time one of us was called in at a private home which had a well supply. They had purchased a storage tank and pump unit. The tank contained approximately a thousand gallons. After the pump had filled the tank so that the gauge would indicate 60 lbs. it would only require about an hour before the pressure would drop so low that no water could be obtained in the house. It indicated that there must be a leak somewhere in the line. After testing for about an hour the leak was located out in the yard. This was later dug up and repaired. But what interested us was that almost 80 per cent of the tank from the bottom toward the top had a sweaty appearance on the outside and the upper part was dry. This indicated very conclusively that the upper 20 per cent was compressed air, and, from this, energy was obtained to force the water out of the tank and into the house.

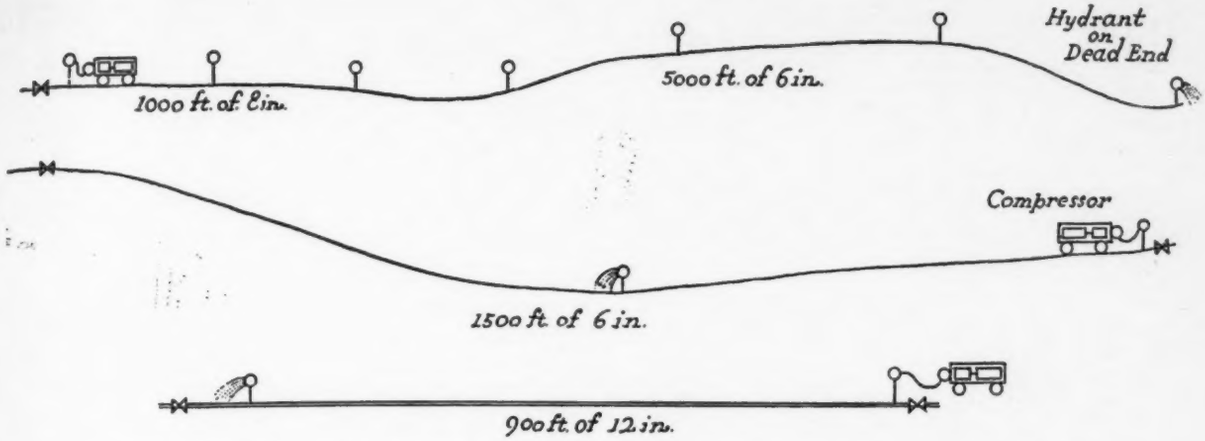
Now the third experience with compressed air followed almost immediately when we received a complaint from a customer that was receiving a large quarterly (metered) water bill. Since the bill was approximately $40 per quarter, and as the estate being supplied was of such large proportions, we assumed that it was legitimate consumption.

We immediately made an inspection. The pipe line consisted of about 1,200 feet of 2-inch cast iron cement-lined pipe with the meter in a pit at the property line. We inspected and tested the entire line with the exception of a swampy area of about 100 feet across it. We could not find a resemblance of a leak. The only place left was the swamp, which was covered with water. We thought we would try compressed air. We got our air compressor and placed it near the meter pit. We disconnected the meter and connected the air hose to the outlet pipe of the meter setting. We started up the compressor and turned the air into the pipe line and in about three minutes bubbles appeared out in the swamp water. We marked the spot with a stake and later, when the water receded, we dug it out and found the hole in the pipe that was responsible for the waste.

So, from these experiences, we felt that by applying compressed air into a pipe line and having a hydrant open, it would force the water out. With this thought in mind, it was not long before we had an opportunity to try out our idea, and it exceeded our fondest expectations. We have used it several times lately, so successfully that we have told some of our friends about it and they too are highly pleased with the results.

Procedure Developed

In making connections, the lay-out must be looked over carefully to find the highest place possible on the section to be emptied and there connect in the air. Then the hydrant at the lowest point must be opened wide. It is not necessary to close off any services.



Sketch Showing Three Conditions Wherein Water Removal with Air Compressors Was Successful

When the district is shut off and the air compressor is connected, either to a hydrant or house connection, and the relief hydrant is opened, turn the air into the main, and almost instantly the water will start coming out of the waste hydrant. The compressor that we employ normally indicates 100 lbs. when the tank is full. The pressure will almost immediately drop from 100 lbs. to 60 lbs., and sometimes will gradually drop to 40 lbs., depending upon the size of the pipe. The larger the pipe, the greater the drop in pressure.

Some Experiences

Our outstanding performance was in connection with the emptying of a long line consisting of 1,000 feet of 8-inch pipe and about 5,000 feet of 6-inch, terminatnig in a dead-end district.—See sketch. In this section we had planned several changes and we had seven holes dug. One was for the laying of a 6-inch line across this street. Three hydrants had to be moved back and gates cut in on the branches and three extra gates cut into the main line. We connected up our compressor to the first hydrant

Removing Water from 6-In. Main by Air Pressure. Section 480 Ft. Long Emptied in 3 Minutes

and opened up the last hydrant at the end of the line. We closed off the district at 8 a. m. and then turned the air into the line, and in thirty-five minutes the water was forced out, and air then came out of the last hydrant, indicating that the water was removed. During this thirty-five minutes the water came faster and faster, due to the fact there was progressively less water and less weight to push with each succeeding minute.

During the day we cut into this pipe line in seven places and none of the openings had enough water in them to even require common rubbers over the shoes. In fact, six of them were *completely* dry. You can readily see the value of this procedure. It is inexpensive, quick, and in most instances a dry trench can be had. You can well imagine how long it would have taken to complete the job if the cuts were made and hand or gasoline pumps had been used in the removal of the water from the trench.

Another experience on a 6-inch line 1,500 feet long was interesting in that a hill was within the area. Half way along the line at a low point there was a hydrant which was used to remove the water. At one end of the line was another to which we connected our compressor line. This hydrant was about 5 feet higher than the hydrant we were to blow the water out through. At the other end of the section of line was the gate, located at a point about 25 feet higher than the hydrant which was to be used to blow out the water.—See sketch. After closing the gate the two hydrants were opened and the compressor turned on. In a very few minutes the water ceased to flow and air came out of the hydrant. The compressor was closed off for about a minute, which allowed the water on the hill to flow down into the lower area. Then the compressor was turned on and more water gushed out. This procedure was repeated several times until no more water came out of the hydrant. The tee was then cut into the line and pipe laid to a gate. At no time did water come out of the cut pipe.

This scheme has also worked out satisfactorily on a 12-inch pipe line of about 900 feet in length and nearly level.

We have also located the ends of our two intake suction lines from our two sources of supplies. At our main station we have a connection around our well house connected into our discharge system in order to reverse the flow of water in the suction line. There was a connection wherein we could connect our compressor. After closing the gate on the suction line in the well house the air was turned on and bubbles appeared all along the line for about 300 feet out into the lake. When the air reached the end of the pipe it then came to the surface, causing the water to bubble up sometimes 2 feet above the surface. It showed very conclusively the location of the pipe and the end of it.

This method of removing water from pipe lines has eliminated all physical effort in securing a dry trench and has materially speeded up the work. It is inexpensive and almost always leaves a dry pipe and trench.

Standards of Practice

The Indianapolis Water Co., Indianapolis, Ind., keeps a code-book which outlines procedure in all kinds of situations, even to specifying the kind and color of paint to be used in various places. The "code" could never be complete because of changes from time to time, as conditions warranted. However, it served as a valuable guide and a record of previous decisions.—*Monsanto "Chemical Topics."*

Dry Ice as Well Cleaner

Dropping 200 pounds of dry ice down a well casing and thereafter closing the well tight, a well driller has found effective in opening of well screens. As the dry ice "melts," the liberated carbon dioxide gas builds up a pressure which forces the water in reverse of usual flow out through the well screens and surrounding sands or gravel. The pressure is watched on a gage on the well and the relief valve is opened to avoid pressures above 150 lbs.—*Monsanto "Chemical Topics."*

WATER WASTE SURVEYS

By A. D. STALKER*

Waste control, as a subject, can be divided very conveniently into two parts: First, that having to do with wastage which takes place inside houses and other buildings; and second, that concerned with wastage from the underground portion of the distribution system.

Meterage as a Remedy

By far the most effective method of dealing with the wastage that takes place inside buildings is by having services 100 per cent metered. The person who has to pay for water through a meter can generally be depended upon to be economical in its use. To make the watertaker pay for the water he wastes, will reduce that waste to a minimum.

In cities or towns where none, or only a small percentage of the services are metered, the control of waste from defective plumbing fixtures is much more difficult. Systematic house-to-house inspection, regularly maintained by a permanent staff of inspectors, will prove a great aid in keeping this class of waste within reasonable bounds. These inspections must be frequently repeated, and to be effective must be supported by strong laws and good plumbing ordinances.

In Ottawa when defects in plumbing fixtures are located by any one of the inspectors, the owner of the property is given 48 hours in which to make the necessary repairs. The inspector re-examines the premises at the expiration of the 48 hours, and if repairs have not been made, the service is shut off, and before it is again turned on repairs must be effected, and the owner is compelled to pay the sum of $1.00 as a charge for the services of the turnkey.

The public in general seems to think that the information contained in educational literature dealing with the importance of attending to small leaks and wastes should make a great impression—on somebody else. The value of this type of waste-control work is debatable. The writer's opinion is that the results obtained are not worth the trouble and expense of getting up and distributing the literature. *The only cure for waste due to carelessness is metering.*

The Pitometer

The second phase of waste reduction has to do with the location of leakage from the underground portion of the distribution system. To find the leaky parts of the underground system, a survey must be made to ascertain where the water goes after leaving the pumps, and what parts of the system receive excessive quantities. This can be accomplished by means of a pitometer.

The pitometer is an instrument that adapts the "Pitot" principle to the measurement of water. Two tubes enclosed within a metallic sheath are introduced into a water main through a 1-in. corporation cock. The tubes are set in such a position that one orifice faces directly up-stream and the other directly down-stream. They are connected by means of rubber tubing to the two legs of a glass U-tube containing a liquid of a specific gravity higher than water and which will not mix with it. The difference between the pressure on the downstream and on the up-stream orifices, which is the pressure due to velocity, causes a deflection of the liquid in the arms of the U-tube, and from this deflection the flow is calculated.

The prism photo recording pitometer makes a continuous photograph of the U-tube fluctuations upon a sheet of sensitized paper attached to a drum revolved by clock-work. The drum can be geared to complete a revolution in 12, 24 or 48 hours. From this photo record the flow through the main can be ascertained for any time during the gauging.

To measure accurately the flow through mains with the pitometer, the ratio of the mean velocity to the center velocity must be established, as the orifices of the instrument are set at the center. This ratio is called the "pipe coefficient" and is established by traversing the pipe. A pipe traverse is made by taking readings of the velocity at intervals across the pipe sufficiently close together to make a smooth curve when plotted. The pipe section is divided into rings of approximately the same area. The mean velocity of each ring in feet per second multiplied by the area of the ring in square feet, gives the ring volume in cubic feet per second. The mean velocity for the whole pipe section is the total of these ring volumes divided by the area of the pipe. The mean velocity divided by the center velocity is the pipe co-efficient. On large mains it is desirable to traverse the pipe on two diameters 90 degrees apart and in the same plane. By using two rod meters, one can be left at the center of the pipe and the traversing done with the second, and readings taken when the center velocity is the same in each case. The pipe coefficient is the same for all velocities in the same pipe at any particular point, and it is upon the discovery of this principle that all pitometer gaugings are based.

*The late Prin. Asst. Water Works Engineer, Ottawa, Ont.

How Pitometer Survey Is Made

A pitometer survey should properly start at the pumping stations, and the discharge from the pump checked. When this has been done, I think it good practice to test all trunk or feeder mains before dividing the system into districts. These mains taken separately can be quickly done, and the distribution of water through that part of the system fed by them is interfered with for a much shorter time than would be the case if they were to form part of a district. Furthermore, trunk mains are usually so spaced as to form excellent district boundaries.

More accurate results can be obtained if the pitometer tap is placed on a small main feeding into the trunk main than would be the case if the tap were to be placed on the trunk main itself, as a flow that would cause scarcely any deflection of the liquid in the U-tube if the tap were on the large main, would cause a sufficiently great deflection to give an accurate measurement of the flow if the tap were on the smaller main. The tap may be placed in such a position as to serve as a gauging point both for the trunk main and one of the districts.

The next step is the dividing of the system into districts. This work must receive careful consideration. A district should be of a size that can be conveniently sub-divided in one night during the hours of minimum consumption, and the boundaries laid out with a view to causing as little interference as possible with the circulation through the balance of the system. The gauging point should be on a main of such a size that a velocity of about 4 ft. per sec. would supply the maximum normal demands of the district, without any allowance for leakage. This velocity will give a deflection of about 17 in. on the U-tube, using a liquid of 1.25 specific gravity. The maximum consumption would not be likely to cause a velocity great enough to blow the liquid out of the tube, and the minimum consumption would cause a fairly high deflection. When the district is first gauged, a velocity higher than the above will probably be recorded ,and a heavier liquid might have to be used. The idea behind choosing a main of this size is to ensure a deflection high enough to give an accurate measurement of the flow when all leaks have been stopped.

It is necessary that those entrusted with waste reduction should become thoroughly acquainted with the conditions that exist in the various districts. The population and how it is distributed, and whether the area is industrial or residential, must be known in order to determine what quantity of water would be sufficient for its needs.

If the survey being made is an original one, a 48-hour record should be taken, including a Sunday if possible. Very careful records should be kept of all flows recorded and work done, and of any peculiar or unusual conditions that may be found to exist, as this information will, without doubt, be of great assistance in later surveys. Weather conditions and any circumstances which might affect the consumption of water should be noted.

When the flow is to be gauged, the district is cut off from the rest of the distribution system by closing all the valves on the boundaries, excepting on the pipe to which the instrument is connected. To make sure that the valves are holding properly, and that no water is getting in, either through them or through services that may be joined up inside buildings and connected to mains on both sides of a boundary, the main feeding the area enclosed should be closed and a hydrant at the highest point within the boundaries opened. If the hydrant is not off, the point at which the water gets into the district must be located, and

the flow stopped. When it is assured that the whole supply passes through the main to which the instrument is connected, the district is ready for the taking of the record. Precautions should be taken to prevent street flushers drawing water from hydrants located within the district boundaries while the record is being taken. It is advisable also, to have a man with a valve key stationed at a fire hall either in or convenient to the enclosed area, so that valves could be opened with as little delay as possible in the event of a fire breaking out. If a fire occurs in a district while the flow is being recorded, the record will be ruined, and opening the boundary valves cannot make it any worse.

If the record taken indicates that an excessive amount of water passes the gauging point, and that the flow remains high during the hours in which very little water would be used, the district should be sub-divided. For subdivision purposes the mechanism revolving the drum of the pitometer is geared to complete a revolution of the drum in twelve hours. This will give a movement of an eighth of an inch in five minutes.

One method of sub-dividing is to divide the whole district into sections as small as the spacing of the valves will permit, and then closing a section down for a short period (at least five minutes) and re-opening it, and repeating this operation with other sections, until all have been shut down. Another method is to start at the boundaries and work towards the instrument, gradually reducing the size of the district, and as the new boundary valves are closed, the old ones are opened. The method used will depend on the conditions that exist in the district. With either method, the time each shutdown is completed must be noted. It is important that all valve operations should be checked over before leaving the district, to make sure that no valves are left closed.

Locating the Leaks

When the subdivision record has been interpreted we will know the quantity of water each section of the district received. The sections that receive excessive quantities should be carefully gone over and the reason for the large flow ascertained. It is a good idea to have a plumbing inspector make a special examination of the fixtures in all buildings in these areas. If this inspection fails to account for the flow, it is assumed that the cause is underground leakage.

There are a number of methods usually employed to give the exact location of underground leakage. The one most generally used, and the one by which a great majority of leaks are found, is by sounding. There are a number of instruments on the market devised to help in picking up sounds, and those that I have used have proven of great assistance. The procedure is to sound all the valves, hydrants and services in the suspected area, and sometimes it is possible to get closer to the source by driving rods down to the main. It is remarkable what an experienced man can accomplish by sounding. In a great many cases he can not only tell where the leak is, but its nature—whether it is a blown joint, a split main, or a burst service pipe.

There are, however, a number of cases in which the sounds picked up are confusing. Where there are two or more leaks close enough together for the sounds to overlap, it is difficult to isolate the sound from one leak and trace it to its source. Leaks that discharge under water produce a sound that is often misleading. Then there is the abandoned service that has not been properly blanked at the main.

Other methods used in conjunction with sounding include testing the pressure at different points until the point of minimum pressure is located; noting the flow in sewers at the manholes; pounding the road surfaces to endeavor to locate cavities beneath the pavement, and searching in cellars and excavations for dampness.

If the above expedients fail to locate the leak, the primitive of digging is resorted to. It is quite probable that the first hole put down will not be in the right place, but from the conditions that exist at this point, a second hols is usually all that is necessary.

Water appearing any place should be looked on as a possible leak, if the reason for its appearance is not apparent. The following is offered as an illustration: Some years ago, this city had a serious epidemic of typhoid fever. Water from any source other than the city mains was in great demand. During this time the writer noticed people drawing water from what appeared to be a spring located at the bottom of a hill. Those familiar with the locality insisted that this spring had always been there, and the city had had a sewer installed to carry off the overflow from it. A sample of the water was analyzed and the analysis showing that the water was very similar to that supplied by the city, the area in the vicinity of the spring was examined. At the top of the hill a 2-in. service that had been installed some thirty-odd years previously, was found to be running full bore. This was stopped and the "spring" immediately dried up.

Other Duties of Waste Reduction Department

In addition to the work outlined above, it is the duty of the department in charge of waste reduction to attend to all cases of flooding of cellars. The first thing to be done in these cases is to find whether or not the water department is responsible. In most cases a test of the electrical conductivity of a sample of the water is sufficient to decide. If the result of this test is not conclusive, an analysis of the water is made, and if it shows that the water comes from the mains, the leak is located by one of the methods mentioned above.

When serious breaks occur in the distribution system they usually give plenty of surface indication as to their locality. These are attended to by the trouble department. Bad breaks do occur without giving such indication, however, and these are followed up by the waste-reduction department. In such cases, the department first gets in touch with all the fire halls in the city, each of which has a pressure gauge installed, to find if possible an area in which the pressure has dropped. If no indication is given in this way, men are sent out to go over those parts of the system where it would be possible for the water from such a break to escape without surface indication. To know where to send the men requires an intimate knowledge of sub-surface conditions throughout the city. Pipes crossing waterways and mains in rocky sections through which large sewer or other excavations have been cut, should be sounded, and if the leak still remains unlocated, short readings of the flow to districts is resorted to.

Blotting Out Waste

Safe Water
delivered night and day
Costs Less
than anything else you buy
· · *but* · ·
Don't Ignore Leaks!

Satisfied customers are worth more to us than revenue secured from water *uselessly* passing through meters.

INDIANAPOLIS WATER CO.

What Leaks May Cost

Size of Leak	Gallons per 24 Hours	Gallons per Month	Cost per Month
½"	47,600	1,451,800	$156.21
¼"	12,300	375,150	60.05
⅛"	3,200	97,600	19.65
1/16"	860	26,230	6.35
1/32"	215	6,550	1.97

(Above estimates are based on Indianapolis pressures without allowance for friction loss)

The above is a reproduction of the top side of a little blotter sent out to customers, reminding them of the high cost of allowing fixture leaks to persist. If as good at blotting waste as ink, the scheme is praiseworthy.

Incidentally, the Indianapolis Water Company gets in a good public-relations message about satisfied customers being worth more to them than the added revenue from the uselessly metered wastage.

MAINTENANCE OF VALVES AND HYDRANTS

By CARL A. HECHMER*

Hyattsville, Md.

It is surprising, especially in small towns and villages, how little attention is given the maintenance of gate valves and fire hydrants on their water systems. The need of good engineering advice and design is recognized and is compulsory in almost every state. Practically every state health department has a law compelling the submission of plans for approval before a water system can be built. The question of good materials is also generally given the utmost consideration and the best valves and hydrants obtainable, in the judgment of those in charge, are purchased and put into the water system. In many instances they are promptly forgotten until an emergency arises and quick, sure operation is necessary. Unless valves and hydrants are given regular attention and properly maintained, the water works superintendent has no assurance that they will function properly. This fact applies to any make of valve or hydrant or to any other mechanical device or piece of machinery. Unfairly, the failure reflects on the designing engineer or the manufacturer of the material, and the local department is given a clean bill of health.

Valves

All valves on a water distribution system should be inspected once each year. This is the minimum requirement of the Fire Underwriters' Association. However, semi-annual inspection is advisable, if finances will allow it. Not only will the mechanical condition of the valve be assured, but valve boxes covered by paving material or earth will be located and reset ready for immediate operation in emergency. This is especially true in rural and suburban sections with a large percentage of unpaved streets. When a large leak occurs, excitement prevails and considerable time may be lost in locating a valve box. Occasionally a large stone or stones are found down in valve boxes and these conditions are revealed on inspection and removed. In case the valve has to be dug up, uncovering the valve, it is advisable to install new packing in the packing gland, which will prevent digging it up for repacking for a long time. Always repack a valve when it is uncovered for any repairs. Packing is cheap and easily installed while the valve is exposed. To dig up a valve just to stop a packing leak is an expensive operation. Inspection also locates valves which were carelessly or accidentally left closed. Any water distribution system is weakened by gate valves being closed when they should be open.

How a Valve Inspection Should Be Made

In addition to the box inspection, a valve inspection should proceed as follows: First set the valve key on the valve nut preparatory to turning the stem. Pour a small quantity of kerosene or diluted automobile crankcase drainings down the valve key stem. The oil will run down the key to the operating nut, thence to the valve stem and lubricate the valve stem against the packing gland. Finding its way into the packing gland, the packing will be softened and revived. Then operate the valve up and down several times, bringing the gate down into the groove hard each time and then opening the valve about one-quarter way. Valve troubles, preventing complete shutdown, are usually caused by the accumulation of sediment under the seat. Each time the gate is pushed down into the groove a small portion of this sediment is pushed out the sides. The high velocity of the water through the partly opened valve removes what is pushed out and the operation is repeated until the groove is sufficiently cleaned to allow the gate to seat properly. This procedure is especially recommended when valves fail to hold when attempting a shutdown. Of course, if the groove is filled with large stones or jointing material, the valve must be dug up and taken apart for repairs. The writer once operated a 16-inch valve up and down thirty times and secured a perfectly tight shutdown. The valve had not been operated for a long time, having been declared worn out, since it always allowed a large volume of water to pass with the gate turned down hard with levers on the key.

In operating the valve a check should be made of the number of turns on the stem. Generally, for the same size and make of valve, the number of turns to close or open the valve completely is the same, and a check can be made to see if the stem is bent, preventing the valve from completely closing or opening. Either condition should be corrected, as partly open valves weaken the system and, obviously, partly closed valves will not shut off the water.

If the valve stem can be turned around and around with no apparent effect on the gate, the stem is broken and must be repaired.

Geared valves, usually set in manholes, must be given special attention on inspection. The gears should be cleaned with a wire brush and greased with a light clinging grease. The stuffing box should, of course, be examined, and the by-pass valve should receive the same attention as the smaller valves on the distribution system.

Fire Hydrants

Proper care in the installation of a fire hydrant is necessary and makes maintenance less expensive. Proper drainage of the hydrant barrel after the main valve is closed is essential to prevent freezing of the hydrant in northern climates. The best method is to provide a bed of crushed stone or gravel around the bottom of the hydrant. The amount of stone necessary is dependent on the nature of the soil. In loose sandy soils a much smaller drainage bed can be provided than in a clay soil that absorbs water very slowly. A safe margin is to provide sufficient area to allow the drainage of an amount of water equal to twice the contents of the hydrant barrel. Connections are often made direct from the hydrant drain valve to the sewer. However, there are two serious objections, first, the cost and, second, the direct connection between a sewerage system and a domestic water supply, even though the possibility of contamination reaching the water in the mains is remote. Generally water mains are laid on one side of the street and sewers on the other. Hydrants are installed at the curb on the same side as the water mains to shorten the length of the lead. To connect each hydrant drain across the street to the sewer would prove much more expensive than providing a stone drainage bed.

Fire hydrants must be inspected at least twice each year, in the spring and fall. Four inspections annually should be made, if possible, and this number of inspections is advocated by the Fire Underwriters' Association. In high value districts, weekly inspections are often made during extremely cold weather. Arrangements should be made between the water department, the fire department and any other possible users of hydrants to report to the water department immediately after using a hydrant during freezing weather and an immediate inspection made to insure the good condition of the hydrant. Use of hydrants by private individuals or contractors should be allowed only by special permit, and the daily charge made high enough to permit daily inspection during freezing weather. During mild weather the inspection charge can be reduced, as weekly inspections are sufficient.

Valuable data may be secured by the fire hydrant inspection by measuring the static pressure, the residual pressure with one nozzle open, and the flow of water from the hydrant. [See artitcle on making hydrant flow tests (Wilson) elsewhere in this issue.—Ed.] Weak points on the distribution system can thus be determined and improvements due to new installation readily noted. System weakness due to unknown closed valves is also discovered and can be corrected.

Procedure for Making a Hydrant Inspection

The following procedure is suggested for making a hydrant inspection:

First make a physical examination of the hydrant, noting the condition of the operating nut, the nozzle caps and chains, and the general appearance of the hydrant. Then listen for leakage with an aquaphone placed on the operating nut. Then with the nozzle caps on tight open the hydrant valve. If static pressure readings are to be taken, replace one of the nozzle caps with one connected to a pressure gauge. Note if all the nozzles are tight in the hydrant and whether the drain valve has closed properly. If the drain valve has not closed water will appear around the barrel of the hydrant on the outside. Then close the main hydrant valve and take off one of the nozzle caps. Observe the rate of drainage of the barrel to determine whether any obstruc-

*Engineer of Distribution, Washington Sanitary District.

tion has entered the drain valve. To clean the drain valve replace the nozzle cap and crack the main valve. As it requires about three full turns open on the main valve to completely close the drain valve on most makes of fire hydrants, the latter is still open on two turns. The full pressure of the water in the hydrant generally will push out any obstruction in the drain hole and the jet effect of the water through the hole will cut away the stone or earth which has packed around the outside. This simple remedy will eliminate the necessity of digging up the hydrant, in most cases, to correct drainage troubles.

With one nozzle cap off, open the hydrant and thoroughly flush out the water in the lead. At this time the observation of residual pressure and rate of flow should be made. Then close down the hydrant slowly. If the hydrant fails to close off entirely, the trouble is probably being caused by an obstruction under the main valve. Do not put extra leverage on the hydrant wrench, but open the hydrant up again and then close it, repeating the operation several times. Do not attempt to close down beyond the point where the obstruction prevents the main valve from seating properly, as the obstruction will become embedded in the main valve and connot be flushed off, or the valve seat will be damaged. Both valve and valve seat are damaged by attempts to force closing against obstructions. Foreign matter can generally be dislodged by flushing and it is then not necessary to dismantle the hydrant.

After the hydrant is closed and the rate of drainage checked, the stem should be oiled and the nozzles greased with a graphite grease. This kind of grease will not wash off and it prevents the nozzle caps from sticking.

Inspection Records

Record of the inspection should be kept on a field sheet. The location of the hydrants to be inspected can be entered on the sheet in the office. These will allow correct routing and prevent skipping any hydrants. The information on the field inspection sheets can then be transferred to a permanent record card in the office. A card should be in the file for each hydrant, stating the size, make of hydrant, and information regarding pressure at the hydrant. The date of each inspection should be entered on the card together with the observed pressures and rate of flow. Necessary repairs and their costs can also be recorded on the card and a history of each individual hydrant is easily obtained.

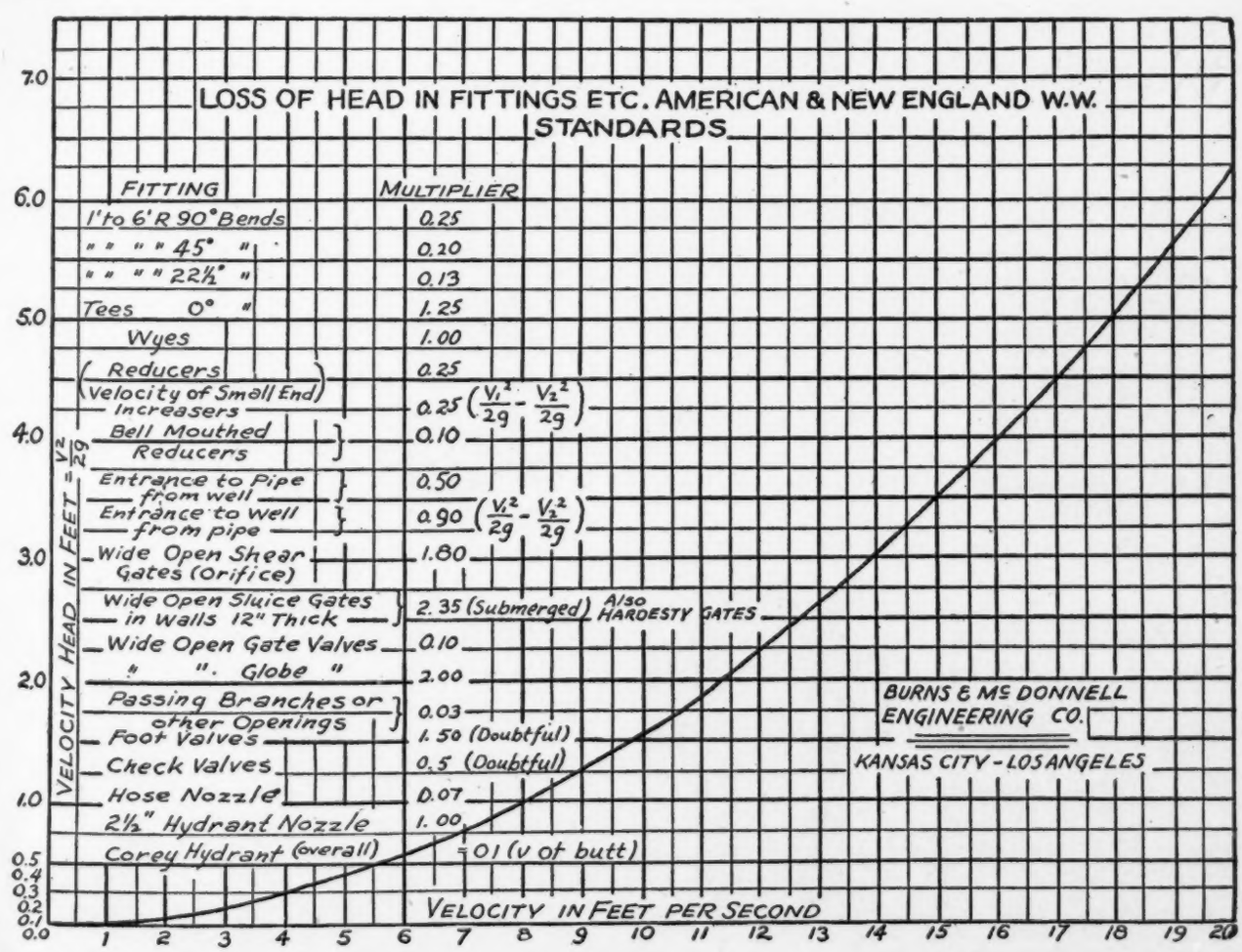
For quick reference the following is suggested: Use a map of the water system mounted on wall board with a push pin to denote the location of each hydrant. The color of the pin can show the condition of the hydrant as reported daily by the hydrant inspectors and the repair foreman. Use a blue pin for a hydrant in good condition, a black pin for a hydrant in need of minor repairs but not out of service, and a red pin for a hydrant out of service. Then when an inspector reports a hydrant out of service it is possible to tell at a glance whether the hydrants around it are in good condition. If several makes of hydrants are in use, it is an advantage to know the make of hydrant before sending out a repair gang so the proper parts can be carried along. By using a small round colored disc under each push pin it is possible to determine at a glance the make of each hydrant, a different color being used for each make of hydrant.

Loss of Head Through Valves and Fittings

(*Burns and McDonnell*)

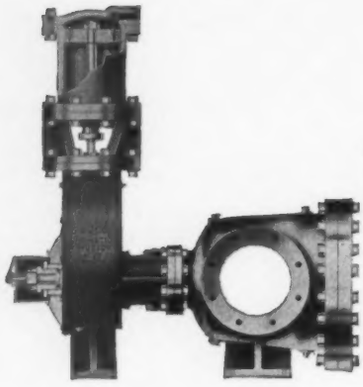
To determine loss of head—Assume flow (Q) to be 5 cu. ft. sec. through a fitting of 12 inch diameter. From Q—AV the velocity (V) = 6.4 ft. per sec. From the chart, velocity head $\frac{V^2}{2g} = 0.7$ ft. Applied to 90 degree bend head loss is $0.25 \times 0.7 = 0.18$ ft. For a tee $1.25 \times .7 = 0.87$ ft.

(Note—Recent correspondence with the producers of this chart cites valves for check valves far in excess of the 0.5 indicated.—*Ed.*)


LOSS OF HEAD IN FITTINGS ETC. AMERICAN & NEW ENGLAND W.W. STANDARDS
FITTING
MULTIPLIER
1' to 6' R 90° Bends 0.25
" " " " 45° " 0.20
" " " " 22½° " 0.13
Tees 0° " 1.25
Wyes 1.00
Reducers 0.25
(Velocity of Small End)
Increasers 0.25 (V1²/2g - V2²/2g)
Bell Mouthed Reducers 0.10
Entrance to Pipe from well 0.50
Entrance to well from pipe 0.90 (V1²/2g - V2²/2g)
Wide Open Shear Gates (Orifice) 1.80
Wide Open Sluice Gates in Walls 12" Thick 2.35 (Submerged) Also HAROESTY GATES
Wide Open Gate Valves 0.10
" ". Globe " 2.00
Passing Branches or other Openings 0.03
Foot Valves 1.50 (Doubtful)
Check Valves 0.5 (Doubtful)
Hose Nozzle 0.07
2½" Hydrant Nozzle 1.00
Corey Hydrant (overall) =01 (v of butt)
VELOCITY HEAD IN FEET = V²/2g
VELOCITY IN FEET PER SECOND
BURNS & MC DONNELL ENGINEERING CO.
KANSAS CITY - LOS ANGELES

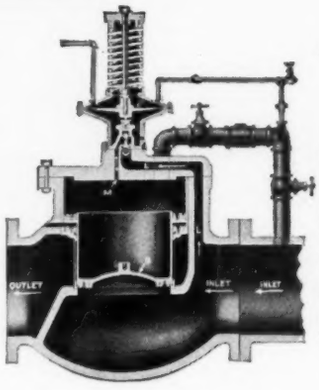
GOLDEN-ANDERSON VALVE SPECIALTY CO.

1350 Fulton Bldg.
PITTSBURGH, PENNA.



THRU-FLOW CONE VALVE

Afford full pipe line flow without friction loss. Always oil lubricated. Axially unseats before it rotates without friction, rub or wear. Especially desirable for sewage disposal service.

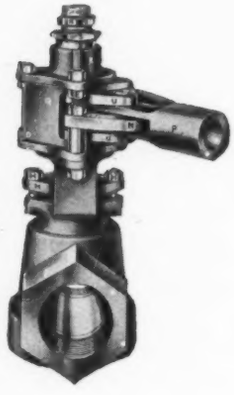


ALTITUDE CONTROL VALVE

Assures uniform water level in tanks, standpipes and reservoirs. Suitable for use in single or two-way line service. Heavy internal bronze mounting and air and water cushioning makes valve indestructible. Sizes to 24".

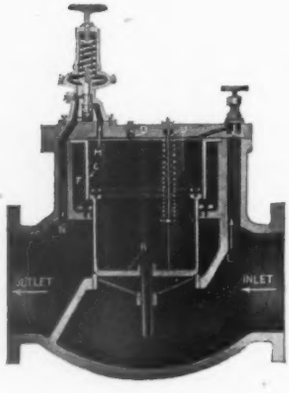
THRU-FLOW PLUG VALVE

Furnished all sizes for lever or handwheel control. Axially unseats and rotates without rub or wear. Easy to operate under hydraulic pressures. Furnished for any liquid services with round port opening.



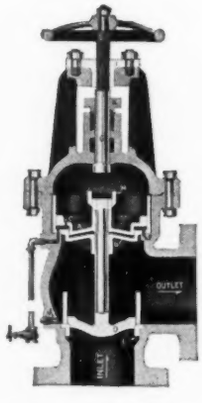
CONTROLLING FLOAT VALVE

Ideal for heaters, vats, tanks, etc. Valve entirely self-contained and operates without water spill. Sensitive in operation and indestructible due to air and water cushioning and heavy bronze mountings. Sizes to 24".



WATER REDUCING VALVE

Assures positive control of low pressure. Air and water cushioning prevents shock or hammer. Supplied with single or dual pilot controls for any service. Sizes to 24".

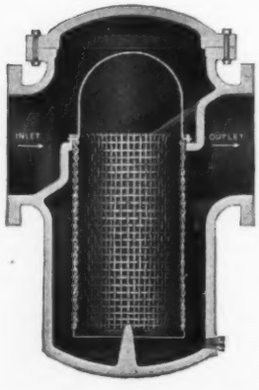


NON-RETURN VALVE

Protect life and property against boiler tube ruptures; also, furnished in Triple Acting style to protect against steam line breaks. Supplied for low and high pressure steam service. Sizes to 12" in angle, globe or elbow patterns.

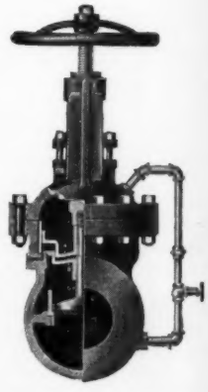
WATER STRAINER

Large capacity with minimum friction loss. Strainer basket quickly accessible and easily cleaned. Basket mesh furnished to suit any service conditions. Sizes to 24".



ENGINE STOP VALVE

The most efficient and dependable automatic stop valve to prevent overspeeding of turbines, engines, etc. Automatically tripped by mechanical or electrical control. Furnished angle or globe patterns to 12" sizes.



HYDRANT DISCHARGE MEASUREMENTS

Practical Methods of Making Measurements; Computing and Applying Results

By P. S. WILSON*
Water Works Consultant, Glen Ridge, N. J.

The measurement of the discharge or flow from fire hydrants is a common procedure for engineers engaged in testing the fire fighting capacity of a water system. The fact is frequently overlooked that such measurements may also be very usefully applied to many other vital problems with which the operator of a water supply system is regularly confronted. It is likewise not always realized that this work may be performed with but a small expense for equipment and without the need for special technical training.

Actual measurements of the flows taking place in a water distribution system may furnish extremely valuable information to the water works operators. A water distribution system is different from most of the equipment with which other business is conducted. It is buried underground and is not subject to ready inspection. The greater portion of it has not been seen for a generation or more. Its present operator has never seen most of it and almost all he knows of it is what he has been told second or third hand or what he learns from maps and records which are in many cases woefully deficient. What information he does obtain about his system is mostly history,—what it was when it was last seen, years before, not what it is now. It is on account of these conditions that actual tests and measurements are of such great value. One can authorize for a long time as to whether a certain valve is open or shut and one may even operate the valve one way or another and still not know much more than before. But if the water in proper quantity flows through that valve and evidences itself on the other side, then the question is settled and there is no more possibility for argument.

There are two principal methods of making field measurements of the flows in water distribution systems. One of these is by means of the Pitot orifice tube inserted through a corporation cock in the side of a main. Such measurements when properly applied are of inestimable value. However, a method, of making tests, which is more readily available to the average operator, involves the measurement of hydrant discharges and less time, expense, and equipment are necessary therefore. Measurements so made are not, of course, a complete substitute for Pitot measurements in the pipes, but in many cases they may suffice in themselves to answer the questions at hand. Even if they do not, they always form a valuable guide and adjunct in the making of further and more elaborate tests, if these are later found necessary.

Methods of Measuring Hydrant Discharge

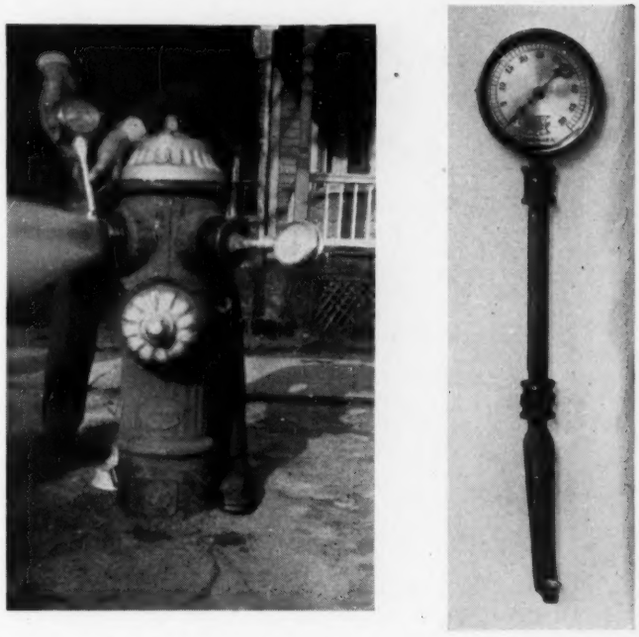
Measurements of the discharge from an ordinary fire hydrant with sufficient accuracy for most practical purposes is not difficult. By the exercise of care and good judgment, results may be obtained within fairly close limits of accuracy. Rough and ready methods are for the most part amply sufficient, since, for the purposes usually involved, the conclusions arrived at would not be changed by a variation of five or ten per cent one way or the other in the test results. Some of the rather approximate methods to be given must be judged with this fact in mind.

The discharge from a hydrant nozzle is determined from the size or cross sectional area of the emerging stream and from the average velocity of that stream. From these two figures the discharge may readily be computed or may be directly read from tables or diagrams such as those appended to this article.

Measuring Nozzle Diameter—Observation of flow from hydrant nozzles shows that it completely fills the nozzle, as a general rule. Therefore, a simple measurement of the internal diameter of the hydrant nozzle serves to make known the diameter of the stream of water. The entrance to the nozzle from within the barrel may occasionally (particularly in some old styles of hydrants, and hydrants with independently gated nozzles) be sharp enough to cause the emerging stream to be contracted slightly below the size of the nozzle and if such an effect is noted it should be allowed for in the diameter used. The internal diameter of each nozzle used should be carefully measured to the nearest one-sixteenth of an inch. An ordinary carpenter's rule is satisfactory for this purpose.

Determining Stream Velocity—The average velocity of the emerging stream of water may be determined in either of two ways. The most common method is by the use of a hydrant Pitot tube which may be inserted into the stream and which transforms the velocity head of the stream into the equivalent pressure head and registers it on an attached pressure gage. This instrument is here pictured. It consists of a hollow blade or "cut-water," shaped so that it may be thrust into the stream without unduly deflecting it. At the end of the blade is a small opening which points directly against the flowing water. The force of the stream striking into this opening creates a pressure in it which is transmitted through the hollow blade and handle to the pressure gage. The gage is an ordinary good pressure gage, except that it should be graduated to read more closely than most gages. The gage most frequently used is graduated every pound and only reads up to about fifty pounds per square inch pressure. It must be a good grade of gage to maintain its accuracy with such close reading. For some purposes it is of value to have a very low pressure gage graduated to half pounds. Sometimes the Pitot tube and the gage are held in place in the stream by a device which clamps over the outside of the nozzle. This device is not ordinarily considered necessary, however, and its use results in greater damage to the Pitot tube if struck by a stone or other object carried by the water. The edges of the blade and the small orifice into it must be kept sharp and symmetrically shaped or the accuracy of the instrument will be seriously affected.

In use, the Pitot tube is held in the stream and the pressure read while the small orifice is held at the center of the stream and pointing directly against the flow. Occasionally on large nozzles it is advisable to take a rough average of the pressures across the stream at different points horizontally and vertically. In most cases the pressure at the center will be found to be practically the average. In no case should the pressure very near the edge (within about one-fourth inch) be considered.



Two Methods of Determining Velocity of Nozzle Discharge. (Gage on Pitot Tube Held in Stream and Gage, Indicating Barrel Pressure, Show Practically Same Readings)
Hydrant Pitot Tube with Gage at Right

*Now Technical Asst. Secy., A.W.W.A.

The other method of determining the velocity of the stream, and one which has been occasionally found more convenient by the writer, consists merely in placing on one of the hydrant nozzles a cap having an ordinary pressure gage tapped into it then allow the discharge to take place through the other nozzles. Due to the free discharge from the nozzles, practically all of the pressure head remaining in the barrel during the flow is transformed into velocity head in the jets. Since that is practically the only source of velocity head in the jets, the ordinary pressure gage indicating the pressure in the barrel will read substantially the same as a gage on a Pitot tube held in a jet. This fact may be readily confirmed by trial. In this way the discharge of a hydrant may be measured with fair accuracy, without the Pitot tube, merely by the use of a pressure gage, the gage reading being used to compute the discharge in the same manner as if it were a Pitot tube reading. The same type of gage should be used for this method as described above for the Pitot tube. Any pressure gage may be used, however, the accuracy of the results depending upon the accuracy of the gage and the closeness of the graduations and readings.

An accompanying illustration shows a Pitot tube with gage being held in the stream from one hydrant nozzle while a pressure gage on the other nozzle is at the same time indicating the pressure in the barrel. This illustrates the two methods of determining the velocity head of the stream. Unfortunately the photograph does not make it possible to see what the gages are reading; actually they show the same—18 pounds per square inch. In using the Pitot at low velocities, where a quarter pound makes an appreciable difference, the instrument should be held horizontally so that the pressure gage will be at the same elevation as the nozzle.

With the same accuracy of gage reading the only inaccuracies in the second method as compared with the use of the Pitot tube are in the fact that there is a slight loss of head in entering and flowing through the nozzle and in the assumption that the velocity head in the barrel at the point of pressure reading is zero. This latter assumption is justified because the velocity in the barrel is low compared to that in the jet and the pressure reading is taken opposite or above the other nozzles which are discharging. In any case, as before mentioned, trial will show that the results are in general substantially the same for both methods. If the hydrant Pitot tube is at hand, its use is best and most convenient; the availability of the other method, however, should always be borne in mind.

The pressure gage on one nozzle, of course, prevents the use of that nozzle for the discharge of water. This is not always a disadvantage, however, particularly when the hydrant is equipped with a steamer nozzle which may be used for attaching the gage.

A fact which may readily be perceived from the foregoing is that, when measuring the velocity with a Pitot tube, readings need only be taken (except as a check) in one of several nozzles discharging simultaneously because readings in all of the nozzle streams should be practically alike.

Computation of the Flow

By the measurement of the nozzle diameter we now have obtained the diameter of the stream of water, and from the pressure gage reading we have obtained a figure which bears a known relation to the velocity of the stream. The formula for the discharge may now be readily derived from the fact that:

Discharge = (area of stream) × (average velocity)

If d = the internal diameter of the hydrant nozzle in inches, then, using the formula for the area of a circle, the area of the stream is $\frac{3.14xd^2}{4}$ square inches. For convenience in computing, this is divided by 144—the resulting formula being $0.00545xd^2$ to obtain the area of the stream in square feet.

The pressure gage reading, in pounds per square inch (p) is changed to feet of water head by multiplying it by 2.31. A fundamental hydraulic formula states that the velocity of the stream of water is equal to the square root of the pressure head multiplied by the square root of two times the acceleration of a falling body, due to gravity. This latter (g) is a constant and is equal to 32.2 in foot and second units. Therefore:

(a) Velocity of the stream in feet per second =
$$\sqrt{2.31 \times p} \times \sqrt{2 \times 32.2} = 12.2 \times \sqrt{p}$$

(b) Discharge in cubic feet per second =
$$0.00545 \times d^2 \times 12.2 \times \sqrt{p} = 0.0665 \times d^2 \times \sqrt{p}$$

(c) Discharge in gallons per minute =
$$29.9 \times d^2 \times \sqrt{p}$$

The velocity of the stream of water as determined by either of the two methods described does not take into account the very low velocity of the stream around the edges where it is held back by its contact (friction) with the nozzle. To make allowance for this, as well as to allow for a possible slight contraction of the jet, it is necessary to make use of a coefficient in computing the results. This coefficient has been determined experimentally by checking hydrant flow measurements against other and more accurate means of metering the flow. The coefficient should, theoretically, be different for different hydrants, but it is sufficiently accurate for the purposes and means of measurement under discussion to use an average figure which has been found by experiment to be about correct for most cases. The figure most generally used is 0.90 and thus the formula derived above is modified as follows:

(d) Discharge in gallons per minute =
$$0.90 \times 29.9 \times d^2 \times \sqrt{p} = 26.9 \times d^2 \times \sqrt{p}$$

For convenience the 26.9 may be rounded off to an even 27 without introducing an error of importance, resulting in the completed formula:

(e) Discharge in gallons per minute =
$$27 \times d^2 \times \sqrt{p}$$

in which d = diameter of nozzle in inches and, p = gage reading in lbs. per sq. inch.

The Advantage of Tables and Charts

From this formula tables may be constructed in which the discharge is given for each combination of diameter of nozzle and Pitot pressure head and from which the result of the measurement may therefore be read directly without computation. A specimen is shown in Table 1. The discharges in this table are given to the nearest ten gallons per minute. Tables may be made up very conveniently to fit in field note books. For special purposes they may be abbreviated or enlarged either in range or in closeness of reading.

Another method of handling the formula is by the use of diagrams. A particularly convenient form for such a diagram, which the author has never seen in use elsewhere, accompanies this article. In this diagram measurements horizontally from the origin or zero are proportional to the square root of the Pitot pressure head, $\sqrt{p}$. Measurements vertically are proportional to the discharge of the hydrant nozzle in gallons per minute. An inclined straight line passing through the origin then represents each value of the nozzle diameter, (d). A heavy line is drawn for each size of nozzle in use using the theoretically correct value of d,—for example 2½ inches for an ordinary hose nozzle. Light lines are then drawn on the diagram below and above the first ones representing 1/8-inch undersize and oversize of each nozzle. From these three lines values for each 1/16 to ¼-inch under and over the nominal sizes may readily be read on the

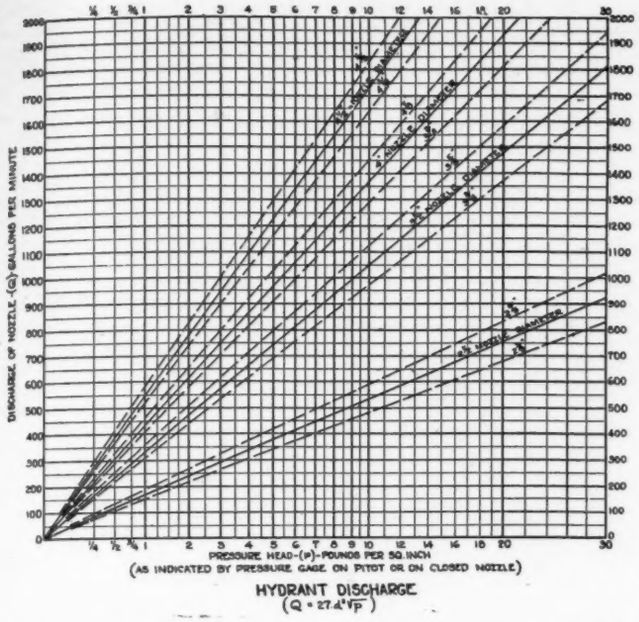
TABLE 1—HYDRANT DISCHARGE*

Gallons per minute = $27 d^2 \sqrt{p}$

Gage Reading—Hoze nozzle diameter in inches [d]

p	2	2¼	2½	2¾	3	3½
¼	70	80	80	80	90	90
½	100	110	110	120	120	130
¾	120	130	140	150	150	160
1	140	150	160	170	180	190
1¼	160	170	180	190	200	210
1½	180	190	200	210	220	230
1¾	190	200	210	220	230	250
2	200	210	230	240	250	260
2½	230	240	250	270	280	290
3	250	260	280	290	310	320
3½	270	280	300	320	330	350
4	290	300	320	340	350	370
4½	310	320	340	360	380	390
5	320	340	360	380	400	420
5½	340	360	380	400	420	440
6	350	370	390	410	430	460
6½	370	390	410	430	450	470
7	380	400	420	450	470	490
7½	400	420	440	460	490	510
8	410	430	450	480	500	530
8½	420	440	470	490	520	540
9	430	460	480	510	530	560
9½	440	470	490	520	550	570
10	460	480	510	530	560	590
11	480	510	530	560	590	620
12	500	530	560	590	610	650
13	520	550	580	610	640	670
14	540	570	600	630	660	700
15	560	590	620	650	690	720
16	580	610	640	670	710	740
17	600	630	660	700	730	770
18	610	650	680	720	750	790
19	630	660	700	700	770	810
20	640	680	720	750	790	830
22	680	710	750	790	830	870
24	710	750	790	830	870	910
26	740	780	820	860	900	950
28	760	810	850	890	940	980
30	790	830	880	920	970	1020

*Discharges shown to nearest 10 gals. per min.


DISCHARGE OF NOZZLE-(Q)-GALLONS PER MINUTE
PRESSURE HEAD-(P)-POUNDS PER SQ. INCH
(AS INDICATED BY PRESSURE GAGE ON PITOT OR ON CLOSED NOZZLE)
HYDRANT DISCHARGE
(Q = 27.4 d² √P)

Hydrant Discharge Diagram. (Courtesy, Community Water Service Co.; this Chart Having Been Prepared by the Author While Connected with the Company)

diagram. This covers the usual variation of the nozzles. It is to be noted that the horizontal distances on the diagram are not directly proportional to the pressures but to the square roots of the pressures. This results in uneven spacing of the figures, but by so constructing the diagram the lines representing the nozzle diameters may be drawn straight, whereas otherwise they would be curved. The uneven spacing of the pressure lines makes accurate interpolation difficult, and therefore enough lines are drawn on the diagram to make this unnecessary. Having made a discharge measurement this diagram is used as follows: Pick the vertical line representing the Pitot pressure reading, follow it up or down to where it crosses the line representing the actual measured internal diameter of the nozzle, estimating where that line would be if the correct one is not on the diagram. Then follow the horizontal lines to right or left and read the discharge on the vertical scale.

A Few Comments

A careful study of the formula and the tables and diagrams leads to a number of important observations on the carrying on of this work. When the Pitot pressure reading is low, a slight difference in the reading will result in a very large percentage difference in the result, whereas at higher pressures a half pound or even a pound does not make much difference. For instance the difference between 1 and 2 pounds per square inch makes about 40 per cent difference in the discharge while the difference between 10 and 11 pounds per square inch makes only about 5 per cent difference. This fact is the reason for making the pressure differences in the table and diagram smaller in the lower range. It also indicates the necessity for making very careful Pitot pressure determinations in the field, particularly at low pressures. Gages should be closely graduated as before mentioned and should have at least three inch dials. On particular work they should be calibrated with a dead weight tester before and after using and corrections applied to the readings if necessary. Gages should be handled gently and with care so as to maintain their accuracy. Since they will probably not read as high as the static pressure in the mains, care should be taken when taking pressures on a closed nozzle not to subject them to too much pressure. Other gages must, of course, be provided for taking the direct main pressures.

Emphasis must be placed on the necessity for keeping the connections between the Pitot blade and the pressure gage absolutely tight. A very slight leak, in fact only a drip which in the general splashing may not be noticed, is sufficient to make the reading considerably in error. The connections should be made up tightly with wrenches and should not be loosened in order to turn the gage into a more convenient position.

It will be noted that a 1/16-inch difference in the diameter of the nozzle makes a much greater percentage difference at high discharges than at low ones. This is the opposite from the effect of the pressures. In spite of this it will usually result in greater accuracy to use as few and as small nozzles as possible in a measurement. The use of steamer nozzles is advised only on work where approximate results would be satisfactory. Further experiments may show that a slightly different coefficient should be used in computing the discharge of the larger sizes of nozzles.

Fire Flow Tests

The making of fire flow tests is the most obvious use to which hydrant flow measurements may be put. Such tests consist in the determination of what amount of water is available at a given hydrant, or at a given group of hydrants, for use by the fire department. This test is the one usually made by the engineers of the National Board of Fire Underwriters in rating a system for fire protection. So much has been written on such tests that they need be only mentioned here. Simultaneous readings are taken on as many hydrants in a group as are needed in order to develop the capacity of the system. At the same time a record is kept at an adjacent hydrant (not discharging), of the residual pressure. From a set of such readings the discharge capacity of the system at that point with any residual pressure may be known.

The residual pressure mentioned above is the pressure remaining in the mains during the time that a flow test is taking place. This pressure is determined by the readings of a pressure gage attached to a hydrant which is *not* discharging but which is located close by and, if possible, on the side opposite to the direction from which the flow is coming. The actual capacity of the distribution system at a given point is usually considered to be the discharge with the residual pressure drawn down to some stated figure. By this method the results of flow tests at different points and on different systems are made comparable. When fire engine pumpers are to be used then the maximum capacity of the system may be considered as the discharge with the residual pressure drawn down to 20 lbs. per sq. in. If reliance is placed on direct hydrant pressure for the hose streams then the residual pressure can not be drawn down nearly so low and the maximum capacity of the system at such higher residual pressures will be less. Sometimes the capacity of a system is referred to as the discharge with a drop in pressure of 20 lbs. per sq. in., in other words, with a residual pressure 20 lbs. per sq. in. less than the original pressure before the hydrants were opened. This will usually be a very different figure from the capacity at 20 lbs. per sq. in. minimum residual pressure.

It is usually difficult or impossible to make a flow measurement at exactly the rate of discharge which will result in the residual pressure desired. It is customary, therefore, to make the measurement at some rate of discharge as near as convenient to that producing the effect desired and then to compute what the discharge would have been at the residual pressure desired. This may be done by applying the fact that the discharge is approximately proportional to the square root of the drop in pressure.

If, for example, the original pressure in the mains before opening the hydrants had been 56 lbs. per sq. in., and the residual pressure during a flow of 2680 gallons per minute had been 32 lbs. per sq. in., then the drop in pressure during that flow was 24 lbs. per sq. in. Suppose now that it were desired to know in this example what the discharge would have been with a residual pressure of 20 lbs. per sq. in. The drop in pressure in that case would have been 36 lbs. per sq. in. It is then merely necessary to multiply the measured discharge (2680 gal. per min.) by the square root of 36 (which is 6.0) and divide by the square root of 24 (which is 4.9).

$$\frac{2680 \times 6.0}{4.9} = 3280 \text{ gal. per min.}$$

which would have been the discharge at 20 lbs. per sq. in. residual pressure.

If Q_1, is the measured discharge with a drop in pressure of D_1; and, Q_2 is the discharge which would have taken place with a drop in pressure of D_2 then the above method may be stated in a general formula as follows:

$$Q_2 = Q_1 \times \frac{\sqrt{D_2}}{\sqrt{D_1}}$$

This method, as stated before, is only approximate and it should not be considered very reliable if the drop in pressure at the measured discharge is very greatly different from the drop in pressure desired. The method is, however, entirely satisfactory for most practical purposes.

Fire flow tests may indicate not only whether the system has the desired capacity or not, but they may be amplified to give

information as to what work should be done to increase the capacity. For example, by taking a record of the pressures in the system during the flow test at various points progressing back toward the source of supply, it may be conclusively shown whether a restriction is in the principal supply mains or whether it is in the local mains adjacent to the test. By cutting out certain mains during the test still further information may be gained as to the actual conditions existing; closed valves or other obstructions, defective hydrants, or large leaks may be discovered and located. This work opens up a great field for the display of ingenuity on the part of the operator since the exact procedure is subject to unlimited variation and depends upon the arrangement of the particular system under test.

For further details and information regarding fire flow tests the reader is referred to a paper published in the *Journal of the American Water Works Association*, Volume 12, No. 2, October, 1924, by Mr. George W. Booth.

Other Uses for Hydrant Flow Measurements

There are many other varieties of tests, measurements and experiments which may be performed on a distribution system through the use of hydrant discharge measurements. They may be used in making determinations of the friction coefficient in certain mains of the system. By isolating a stretch of pipe so that the feed into it is from one end only, a flow through it may be created which can be measured at its discharge from a hydrant or hydrants at the end of the section under test. If pressures are taken simultaneously during the flow at intermediate hydrants or other connections of known elevation along the main, then, from the data so obtained, the loss of head and the friction coefficients of each section may be computed. Obstructions or closed valves may also be located through the unequal drops in pressure in different sections along the line when such difficulties exist.

Such tests are of value in determining the necessity for or advisability of cleaning a main and likewise, in determining the effectiveness of the cleaning after it has been performed. If they are made periodically after cleaning, valuable data will be obtained as to the speed and degree of the return of roughness in the pipe, thereby indicating the true value of the cleaning and the advisability of recleaning or of cleaning other mains. Also the efficacy of corrosion control procedures will be disclosed and the results of changes evaluated.

In those cases where a company's records are inaccurate, loss of head tests may be quickly made to provide an accurate indication of the size of any main which is in doubt.

When flushing out sediment or other deposits from the pipes of a system it is of great value to make a rough check of the discharge of the hydrants or blow-offs in use in order to be certain that a sufficient velocity has been created in the main or mains supplying that point to properly clean them out. From 4 to 6 feet per second is usually considered the minimum that will effectively flush out a main, so that the material remaining will cause no further difficulty by being stirred up by normal flows.

It is difficult to foresee all of the benefits which may come of making tests such as these on a distribution system. One of the greatest benefits is that, no matter what their nature, they will ordinarily result in an unusually thoughtful and detailed consideration of the system on the part of the men who are operating it. The effort to interpret and account for results, and the resulting further tests, will frequently uncover unsuspected conditions quite different from those which originally suggested the tests.

Acknowledgment—At the request of WATER WORKS AND SEWERAGE, the author has revised and added to an article published by him (Journal of the A. W. W. A. for July, 1930), on the same subject. We believe the practical value of this contribution justifies its re-publication.—*Editor.*

[*See also "Pipe Flow Diagram" and "Flow Powergraph" which appear later in this section.*]

Fire Flows Required for Towns of Various Sizes, by National Board of Underwriters

Population	Required Fire Flow, Gallons per Minute for Average City
1,000	1,000
2,000	1,500
4,000	2,000
6,000	2,500
10,000	3,000
13,000	3,500
17,000	4,000
22,000	4,500
28,000	5,000
40,000	6,000
60,000	7,000
80,000	8,000
100,000	9,000
125,000	10,000
150,000	11,000
200,000	12,000

Over 200,000 population, 12,000 gallons a minute, with 2,000 to 8,000 gallons additional for a second fire.

In residential districts the required fire flow depends upon the character and congestion of the buildings. Sections where buildings are small and of low height and with about one-third the lots in a block built upon, require not less than 500 gallons a minute; with larger or higher buildings up to 1,000 gallons is required, and where the district is closely built, or buildings approach the dimension of hotels or high value residences, 1,500 to 3,000 gallons is required, with up to 6,000 gallons in densely built sections of 3-story buildings.

Commercial Pipe Sizes for Fire Streams*

Number of 1 1/4-Inch Hose Nozzles	Ordinary Fire Streams											
	40 Pounds Pressure		50 Pounds Pressure		60 Pounds Pressure		70 Pounds Pressure		80 Pounds Pressure		90 Pounds Pressure	
	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.
1	4	20	6	23	6	25	6	27	6	29	6	30
2	6	40	8	45	8	50	8	53	8	57	8	61
3	8	61	8	68	10	74	10	80	10	86	10	91
4	10	81	10	90	10	99	10	107	12	114	12	121
5	10	101	12	113	12	124	12	134	12	143	12	152
6	12	121	12	135	12	149	14	160	14	172	14	182
7	12	141	14	158	14	174	14	187	14	200	16	212
8	12	162	14	181	14	199	16	214	16	229	16	242
9	14	182	14	203	16	223	16	241	16	257	18	273
10	14	202	16	226	16	248	16	267	18	286	18	303
11	16	222	16	248	18	273	18	294	18	314	18	333
12	16	243	18	271	18	298	18	321	20	343	20	364
13	16	263	18	293	18	323	20	348	20	372	20	394
14	18	283	18	316	20	348	20	374	20	400	20	424
15	18	303	20	339	20	372	20	401	20	429	24	455
	High-Pressure Fire Streams											
	100 Pounds Pressure		110 Pounds Pressure		120 Pounds Pressure		130 Pounds Pressure		140 Pounds Pressure		150 Pounds Pressure	
1	6	32	6	33	6	35	6	36	6	38	6	39
2	8	64	8	67	10	70	10	73	10	75	10	78
3	10	96	10	100	10	105	10	109	12	113	12	117
4	12	128	12	134	12	140	12	145	12	151	14	156
5	14	160	14	167	14	174	14	181	14	188	14	195
6	14	191	14	200	16	209	16	218	16	226	16	234
7	16	223	16	234	16	244	16	254	16	264	18	273
8	16	255	16	267	18	279	18	290	18	301	18	313
9	18	287	18	301	18	314	18	326	18	339	20	352
10	18	319	18	334	20	349	20	363	20	377	20	391
11	20	351	20	367	20	384	20	399	20	414	20	430
12	20	383	20	401	20	419	20	435	24	452	24	469
13	20	415	20	424	24	454	24	472	24	490	24	508
14	24	447	24	467	24	488	24	508	24	528	24	547
15	24	479	24	501	24	523	24	544	24	565	24	586

To convert cubic feet to gallons, multiply by 7.4805.

In calculating above table, the following assumptions were made: Nozzles, 1 1/4-inch smooth bore, playing simultaneously, and attached to 200 feet of best quality rubber-lined hose; pressures measured at hose connections; velocity of water in pipe approximately 3 feet per second.

*Reproduced by courtesy of N. S. Hill, Jr.

ECONOMY OF ELEVATED STORAGE*

By DONALD H. MAXWELL**

The operating records of the Glencoe, Ill., water works furnish a striking demonstration of economy procurable through the introduction of elevated storage. In this case the savings in pumping costs, resulting from use of an elevated tank, are sufficient to cover all annual costs incident to the project.

The Glencoe pumping arrangements and filtration plant were designed to operate in connection with an elevated tank which was omitted in the original construction and the pumps operated against direct main pressures for about 4 years. In 1932, a 500,000 gallon elevated tank was added and now records under the new conditions are available to show a saving of about 33 per cent in power consumption.

The Glencoe filter plant has two motor driven low lift pumps each of two million gallons rated capacity and three motor driven high lift pumps, of one, two and four million gallons rated capacity respectively. In addition there is gasoline engine driven standby equipment. The average daily pumpage is approximately one million gallons, the rates varying from a minimum of approximately 420,000 g.p.d. to a maximum of 3,300,000 g.p.d. The maximum hourly rate of consumption is approximately 5,200,000 g.p.d. and the minimum hourly rate is about 300,000 g.p.d.

Pumping Conditions With and Without Elevated Tank on the System

Comparison of these consumption rates with the installed pump capacities makes it evident that the high lift pumping operating against direct main pressures, with pumps throttled a considerable part of the time, was necessarily inefficient. The low lift pumping was also inefficient, owing to the desirability of maintaining a full clearwell and thus a 500,000 gallons storage. To do this it was the practice to operate the filters more or less continuously with the low lift pumps throttled. At times these pumps had to be operated at 15 per cent of rated capacity.

With the elevated tank in service the high lift pumps now operate intermittently at about their rated capacity and best efficiency. With present practice, maintaining the clearwell storage at not less than 75 per cent full, is accomplished by running one or two low lift pumps which operate at about rated capacity during approximately the same periods as the high lift pumps are in service.

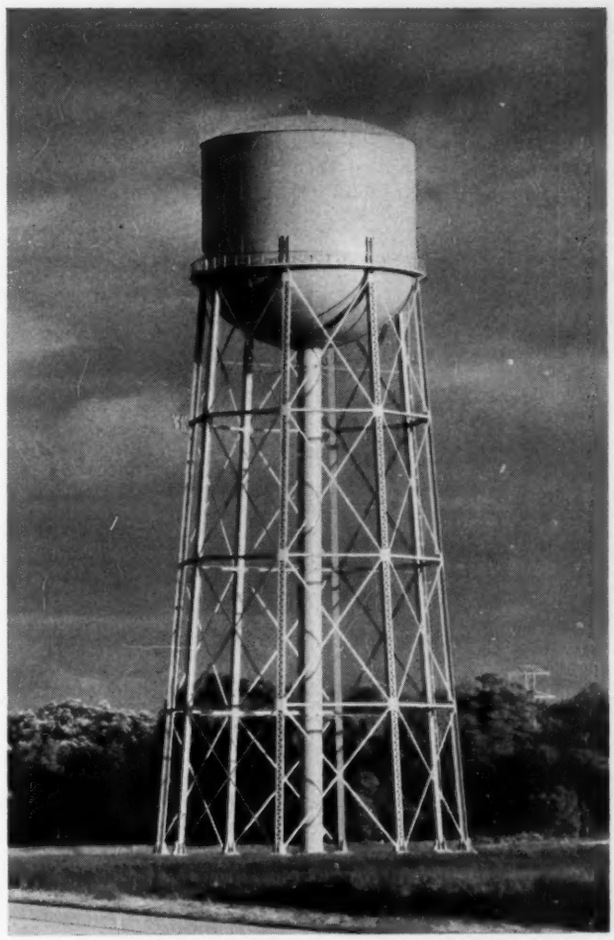
Improved Pressures

The pressures maintanied in the business district when pumping against main pressures varied over an extreme range of 40 pounds per square inch. The variation was from approximately 28 pounds minimum to 70 pounds maximum. Under present conditions, with the tank in service, a very uniform pressure is maintained, having an extreme range not to exceed 20 pounds. From 35 pounds minimum to 55 pounds maximum is recorded at the business center. The changed pressure conditions are clearly shown on the pressure charts, revealing recording gage pressures before and after providing elevated storage.

Savings in Power Consumed

As now operated the pumps run at capacity from 4 to 24 hours a day depending on the season, whereas formerly they ran continuously during periods of light as well as heavy demands. Much of the time they were throttled thus producing a very considerable sacrifice in efficiency as becomes apparent by comparing the power consumption with and without elevated storage, as shown in Table I.

During 1931 (operating direct pressure) the power consumption averaged 1,835 k.w. hours per million gallons delivered to the mains. During the six months of operation with the elevated tank in service, the power consumption per million gallons



500,000 *Gallon Elevated Tank, Glencoe, Ill.*

TABLE I—PUMPAGE AND POWER DATA COMPARING OPERATION WITHOUT AND WITH ELEVATED TANK, GLENCOE, ILLINOIS WATER WORKS

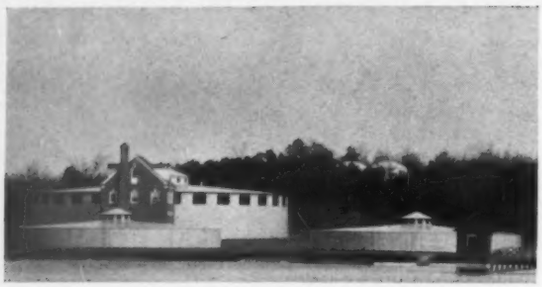
Month	Pumpage, million gallons	Kw.hrs. per calendar month	Kw.hrs. per m.g.d.	Kw. max. demand
1931 (without tank)				
January	21.467	47,600	2,220	87
February	17.568	40,000	2,280	78
March	20.265	45,600	2,250	81
April	22.877	47,400	2,070	126
May	29.097	55,200	1,900	174
June	37.153	60,400	1,620	192
July	55.516	80,800	1,450	249
August	56.960	79,600	1,400	246
September	34.030	62,000	1,820	174
October	27.580	59,000	2,140	114
November	23.116	50,000	2,160	102
December	22.362	47,800	2,140	99
Total or average	367,991	675,400	1,835*	
1932 (only those months with new tank in service throughout month)				
March	21.578	27,400	1,270	117
July	45.083	55,200	1,225	186
August	46.437	56,800	1,225	189
September	38.920	47,200	1,210	168
October	23.700	29,600	1,250	174
November	19.502	25,000	1,280	120
Total or average	195,220	241,200	1,235*	

*Weighted average.

(*Continued on page* 408)

*Excerpts from an article which appeared in Water Works and Sewerage.

**Of Alvord, Burdick & Howson, Consulting Engineers, Chicago.



This new 5 m.g.d. Morse Filter Plant has recently been placed in service at Bristol, Conn.

CHICAGO BRIDGE

Chicago.....2198 Old Colony Bldg.
New York.3390-165 Broadway Bldg.
Cleveland...2262 Rockefeller Bldg.
Dallas....1479 Liberty Bank Bldg.
Birmingham....1586 North 50th St.
Tulsa.....1646 Hunt Bldg.

Plants in CHICAGO, ILL.; BIRMINGHAM, ALA., and GREENVILLE, PA.

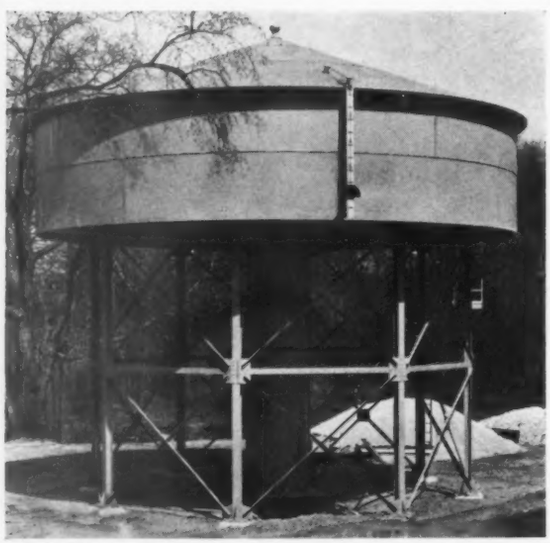
BINS, Storage
BREECHINGS, Steel
CHUTES, Steel
FILTRATION PLANTS
FLUMES, Iron and Steel
GAS HOLDERS
HOPPERS, Steel
PENSTOCKS
PIPE, Riveted steel
PIPE, Welded steel

75,000-gal., Parchment, Mich.

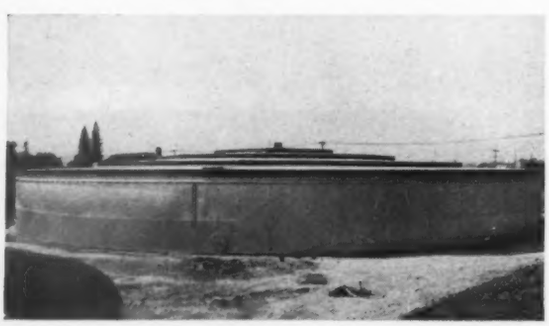
100,000 gal., East Gary, Ind.

200,000-gal., Cullman, Ala.

250,000-gal., Marysville, Mich.



125,000-gal. washwater tank at filtration plant, New Milford, N. J. It is of radial-cone bottom design.



This 2,300,000-gal., all-welded steel water reservoir is one of two installed recently in Alhambra, California.

FACILITIES

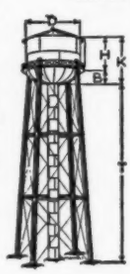
We are equipped to design, fabricate and erect all types of steel plate work, riveted or welded. When requesting estimating figures on tanks, state capacity, height to bottom for elevated tanks, and describe location.

ELLIPSOIDAL-BOTTOM ELEVATED TANKS

This type of tank is built in a complete range of standard sizes as shown in the accompanying table. The diameter of the tank is relatively large and the depth shallow, reducing the variation in pressure between the upper and lower water levels. The proportions of this design are also well balanced, presenting a pleasing appearance. (See first three tanks shown above.)

Ellipsoidal - bottom tanks are equipped with large steel risers riveted or welded directly to the bottom of the tank. The size of the riser varies from three to six feet, the larger sizes being used in northern climates to prevent freezing.

ELLIPSOIDAL-BOTTOM TANK SIZES



Nominal capacity, gal.	Tank dimensions			
	D	H	B	K
40,000	20'0"	13'9"	5'0"	18'9"
50,000	22'0"	14'0"	5'6"	19'6"
60,000	24'0"	14'0"	6'0"	20'0"
75,000	26'0"	15'0"	6'6"	21'6"
100,000	28'8"	16'0"	7'2"	23'2"
125,000	28'8"	21'2"	7'2"	28'4"
150,000	34'0"	16'6"	8'6"	25'0"
200,000	38'0"	17'6"	9'6"	27'0"
250,000	40'0"	20'0"	10'0"	30'0"
300,000	41'0"	23'9"	10'3"	34'0"
400,000	47'0"	23'2"	11'9"	34'11"
500,000	51'0"	24'3"	12'9"	37'0"
600,000	54'0"	26'3"	13'6"	39'9"
750,000	54'0"	32'0"	18'0"	50'0"
1,000,000	60'0"	34'0"	20'0"	54'0"
2,000,000	80'0"	35'6"	26'0"	61'6"

Height to bottom—any even foot.

RADIAL-CONE BOTTOM TANKS

The radial-cone bottom design was developed to permit the construction of large capacity tanks with a small range in head. (See installations shown above at Marysville, Mich.; Decatur, Ga.; Muskegon, Mich.; and Buffalo, N. Y.) Radial-cone tanks are of sound structural design. They present a pleasing appearance. Construction details such as tower bracing, hand railing, etc., may be varied to secure the desired architectural effect. The accompanying table indicates the proportions for various capacities.

STANDARD RADIAL-CONE SIZES

Capacity (Gallons)	Diameter of Tank	Depth of Tank
500,000	61'	25'
750,000	76' 8"	25'
1,000,000	87'	25'
1,500,000	106'	25'
2,000,000	122'	25'

& IRON COMPANY

Houston.....2919 Main St. Boston.1548 Consolidated Gas Bldg.
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PRESSURE VESSELS, Welded
RESERVOIRS, Steel
RECEIVERS, Air
SMOKE STACKS
STANDPIPES

STEEL PLATE WORK
TANKS, Elevated Steel
TANKS, Storage
TANKS, Surge
TANKS, Washwater

Here is one of two 5 m.g.d. Morse Filter Plant units which are installed at Burnt Mills, Md.

500,000-gal., Decatur, Ga.

1,000,000-gal., Muskegon, Mich.

2,000,000-gal., Buffalo, N. Y.

THE MORSE FILTER PLANT

The Morse filter plant is a rapid sand type plant. It is built entirely of steel in convenient sized units. The filters, coagulating basins and reservoirs can be located in concentric circles, providing a compact arrangement. A 5 m.g.d. unit covers a circle 100 ft. in diameter. The advantages are summarized as follows:

1. All-steel construction offers the same advantages that have proved so desirable in large capacity water storage tanks. No seepage, no cracking, less maintenance expense.
2. A worthwhile saving in first cost with all things being equal. Also requires less ground space per unit of capacity than any other type of construction.
3. Modern. Definitely designed to push obsolescence as far into the future as possible.
4. Flexible in both operation and application. Put in capacity needed at present; add more capacity easily and economically at any time in future.
5. Lower operating costs. Very small loss of head through plant means less pumping cost. Cleaning and maintenance is easier and quicker.

WASHWATER TANKS

We build ellipsoidal, radial-cone or special shaped tanks to give exactly the capacity, head, and pressure variation required for washing filters. They are more dependable and economical than direct pressure washing.

RESERVOIRS

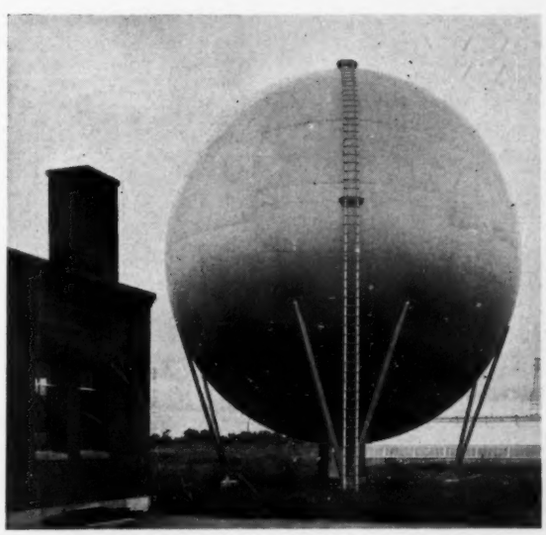
Where natural elevations are available, steel reservoirs provide gravity pressure. They are built in standard sizes or special designs to meet your requirements, of riveted or welded construction, with or without roofs.

SEWAGE GAS HOLDERS

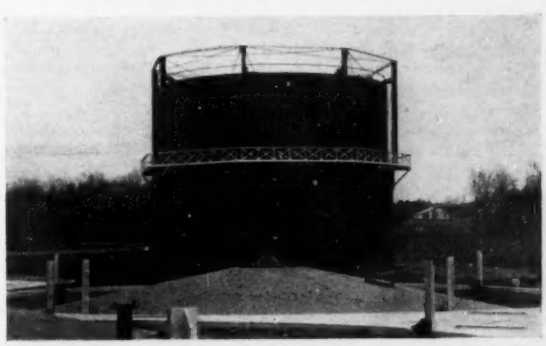
When gas from digesters at sewage disposal plants is utilized, excess quantities produced during peak periods can be stored advantageously under pressure in a Hortonsphere for use during off-peak periods. Hortonspheres are relatively small in size and pleasing in appearance. We also build conventional water-lift gas holders.

INFORMATION

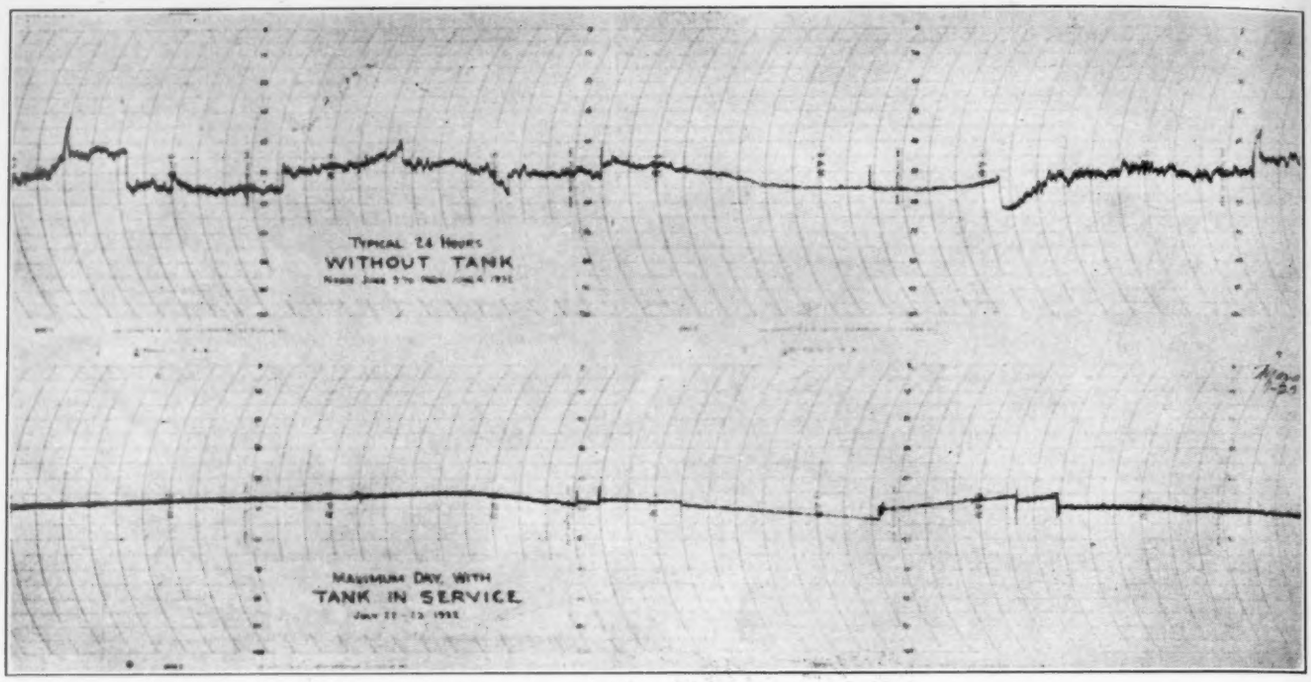
We are glad to supply municipal officials and waterworks engineers with information or estimating figures. Write our nearest office. There is no obligation on your part.



This 50-ft. diameter Hortonsphere is used to store sewage gas at 10 to 30 lbs. pressure at Green Bay, Wis.



50,000 cu. ft. welded steel holder for gas produced from activated sludge at sewage treatment plant, Durham, N. C.



Record Gage Pressures Before and After Elevated Storage Was in Service

pumped has averaged only 1,235 k.w. hours, almost exactly two-thirds of the former power use and much more uniform as shown by the tabulation.

The saving in cost of power due to improved operation, made possible by the tank, cannot be properly shown by direct comparison of power bills for corresponding periods under the old and the new conditions because of the fact that a new power rate was introduced some time after the elevated tank went into service, and also because there has been a decrease in pumpage approximating ten per cent.

The fairest estimate of saving in power cost is obtained by applying the new power rate to the recorded 1931 pumpage as it actually occurred for comparison against the same monthly pumpage if delivered under more efficient operation as now attained with elevated storage. The saving calculated in this manner, amounting to approximately $2,500 a year, is sufficient to cover interest on the investment, depreciation (on sinking fund basis) and maintenance of the tank.

Thus, without added annual cost, the village has been able to avail itself of the many advantages of elevated storage which includes doubling of reserve storage, better fire protection, uninterrupted and more uniform water pressure, greater flexibility of filter and pumping operations and increased plant reliability.

It is worth noting that the saving in cost of power would have been greater if Glencoe had happened to enjoy a uniform rate of power, such as applies in many plants. In reducing the power consumption by 33 per cent the plant is not able to earn proportionately as good a rate. The estimated net average power cost based on the new rate when applied as above explained to 1931 pumpage without the tank nets 1.27c per kw.h., whereas with the tank it is increased to 1.36c per kw.h.

Auxiliary Equipment

The elevated tank is equipped with an altitude valve and a remote indicating water level gage is installed in the pumping station 2⅓ miles away to make practicable the full use of the storage capacity available.

The elevated tank was supplied by the Chicago Bridge & Iron Works. The Glencoe plant is in charge of E. L. Pflanz, Superintendent, and George R. Young is Village Manager.

TABLE OF EFFECTIVE FIRE STREAMS

Using 100 feet of 2½-in. ordinary best quality rubber-lined hose between nozzle and hydrant or pump.

Smooth Nozzle, Size	¾ Inch						⅞ Inch				
Pressure at Hydrants, lbs.	32	43	54	65	75	86	34	46	57	69	80
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70
Press. lost 100′ 2½″ hose	2	3	4	5	5	6	4	6	7	9	10
Vertical Height, feet	48	60	67	72	76	79	49	62	71	77	81
Horizontal Distance, feet	37	44	50	54	58	62	42	49	55	61	66
Gallons Discharged per min.	90	100	116	127	137	147	123	142	159	174	188

Smooth Nozzle, Size	1 Inch						1⅛ Inch				
Pressure at Hydrant, lbs.	37	50	62	75	87	100	42	56	70	84	98
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70
Press. lost 100′ 2½″ hose	7	10	12	15	17	20	12	16	20	24	28
Vertical Height, feet	51	64	73	79	85	89	52	65	75	83	88
Horizontal Distance, feet	47	55	61	67	72	76	50	59	66	72	77
Gallons Discharged per min.	161	186	208	228	246	263	206	238	266	291	314

Smooth Nozzle, Size	1¼ Inch						1⅜ Inch				
Pressure at Hydrant, lbs.	49	65	81	97	113	129	58	77	96	116	135
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70
Press. lost 100′ 2½″ hose	9	25	31	37	43	49	28	37	46	56	65
Vertical Height, feet	53	67	77	85	91	95	55	69	79	87	92
Horizontal Distance, feet	54	63	70	76	81	85	56	66	73	79	84
Gallons Discharged per min.	256	296	331	363	392	419	315	363	406	445	480

PITTSBURGH-DES MOINES STEEL CO.

Tanks—Plate Fabrication—Structural Steel

Sales Offices at: 3432 NEVILLE ISLAND, PITTSBURGH, PA. . . . 933 TUTTLE STREET, DES MOINES, IOWA
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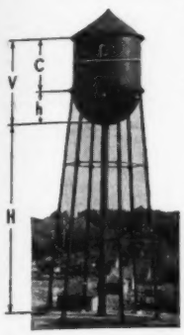
1237 PRAETORIAN BLDG., DALLAS, TEX. . . . 639 RIALTO BLDG., SAN FRANCISCO, CALIF.

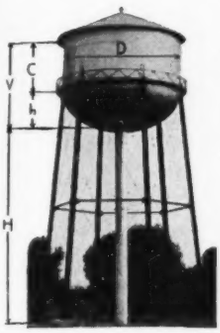
In these tables we have compiled—in compact but complete form—data on steel reservoirs and on the various types of elevated steel tanks. For information as to the application of these various types of tanks, for designs, for specifications, or for estimates—write our nearest office.

Table I—Pittsburgh-Des Moines Standard Hemispherical Bottom Elevated Tanks



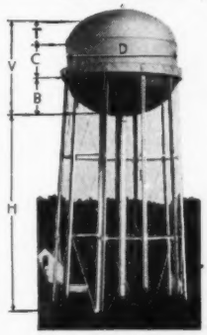
Capacity in U. S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity											
				ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
5,000	9	10 0	11 3	11 3	18 9	31 9	38 3	51 9	58 9	72 9	79 9	93 9	100 9	.....	.....
10,000	13	5 11	11 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....
15,000	13	10 11	16 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....
20,000	13	15 11	21 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....
25,000	15	14 7	19 11	44 8	50 0	69 8	75 0	.....	94 8	100 0	.....	125 0	.....	.....	.....
30,000	15	18 5	23 9	44 8	50 0	69 8	75 0	.....	94 8	100 0	.....	125 0	.....	.....	.....
40,000	17	18 5	25 1	46 8	.....	.....	75 0	.....	96 3	100 0	.....	125 0	.....	.....	.....
50,000	19	17 7	25 7	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4
60,000	19	22 6	30 6	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4
75,000	21	22 6	30 6	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4
100,000	24	22 6	31 0	.....	50 0	63 1	75 0	79 7	91 6	100 0	113 1	116 6	125 0	141 6	153 4
150,000	28	24 2	34 7	46 6	54 10	63 2	75 0	83 4	91 8	100 0	111 10	120 2	128 6	140 3	148 7
200,000	32	23 4	36 1	45 9	54 1	62 5	75 0	83 4	91 8	100 0	112 7	120 11	129 3	141 10	150 2
250,000	32	31 4	45 4	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 8	151 0
300,000	36	28 4	42 5	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 9	151 1
400,000	40	30 0	46 6	44 6	52 10	61 2	75 0	83 4	91 8	100 0	113 10	122 2	130 6	138 10	152 8
500,000	44	29 9	49 2	43 6	51 10	60 2	75 0	83 4	91 8	100 0	114 10	123 2	131 6	139 10	154 7
600,000	44	38 6	58 2	} Tower heights have not been standardized for these capacities and can therefore be built to suit the requirements in each particular case.											
750,000	50	34 9	57 5												
1,000,000	50	52 0	73 9												

Table II—Pittsburgh-Des Moines Standard Hemi-ellipsoidal Bottom Elevated Tanks



Capacity in U. S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity											
				ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
25,000	17	11 9	15 5	46 4	51 8	71 4	75 0	.....	96 4	100 0	.....	126 8	...	.....	.....
30,000	17	14 7	18 6	46 1	51 5	71 1	75 0	.....	96 1	100 0	.....	126 5	.....	.....	.....
40,000	21	11 3	16 9	47 5	.....	.....	75 0	.....	97 5	100 0	.....	126 2	.....	.....	.....
50,000	22	13 2	19 0	.....	57 2	65 6	75 0	85 6	93 10	100 0	113 10	122 2	130 6	142 2	150 6
60,000	24	12 10	19 4	.....	56 6	64 10	75 0	84 8	93 2	100 0	113 2	121 6	129 10	141 6	149 10
75,000	26	13 6	20 8	.....	55 10	64 2	75 0	84 2	92 6	100 0	112 6	120 10	129 2	140 10	149 2
100,000	28	16 2	23 2	.....	51 6	64 7	75 0	81 1	93 0	100 0	114 7	118 0	126 6	143 0	154 10
150,000	34	14 10	25 0	46 0	55 1	63 5	75 0	83 7	91 11	100 0	112 1	120 5	128 9	140 6	148 10
200,000	38	15 5	27 0	46 11	55 3	63 7	75 0	84 6	92 0	100 0	113 9	122 1	130 5	143 0	151 4
250,000	40	18 1	30 0	47 5	55 9	64 1	75 0	85 5	93 9	100 0	115 1	123 5	131 9	140 1	153 1
300,000	40	23 11	34 0	49 4	57 8	66 0	75 0	87 4	95 8	100 0	117 0	125 4	133 8	142 0	155 0
400,000	46	22 9	34 11	48 10	57 2	65 6	75 0	87 8	96 0	100 0	118 2	126 6	134 10	143 2	157 0
500,000	50	23 9	37 0	49 8	58 0	66 4	75 0	81 2	89 6	100 0	112 8	121 1	129 4	146 0	152 5
600,000	55	21 9	39 7	} Tower heights have not been standardized for these capacities and can therefore be built to suit the requirements in each particular case.											
750,000	60	22 4	42 4												
1,000,000	60	35 0	54 0												
1,000,000	65	26 1	47 7												
1,250,000	79	17 4	43 4												
1,500,000	70	37 8	60 0												
1,500,000	79	24 0	50 0												
2,000,000	90' 3"	22 6	50 0												

Table III—Double Ellipsoidal Tanks



Capacity in U. S. Gallons	Tanks D ft.	V ft.	V in.	H
100,000	28	23	8	
150,000	34	26	9	
200,000	38	27	7	
250,000	38	33	7	
275,000	40	33	2	Built to Order
300,000	42	31	7	
350,000	44	36	6	
400,000	46	35	7	
500,000	50	39	2	
600,000	54	40	0	
750,000	Dimensions on request			
1,000,000				

Table IV—Railroad Type Tanks

Capacity in U. S. Gallons	Tank Dimensions D ft.	C ft.	C in.	V ft.	V in.	H
20,000	15	10	9	16	2	Any height from 15' 0" to 40' 0" in multiples of 5' 0"
25,000	15	14	7	19	11	
30,000	17	12	7	19	0	
40,000	19	13	1	20	6	
50,000	21	13	1	21	1	
60,000	24	10	1	20	3	
75,000	24	15	1	23	10	
100,000	28	13	5	23	7	
150,000	28	14	2	24	7	
200,000	36	15	1	29	2	
250,000	38	17	3	33	3	
300,000	38	23	11	38	3	

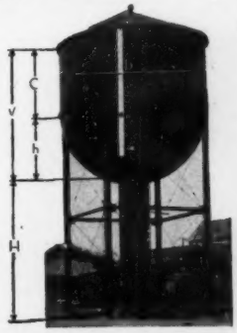
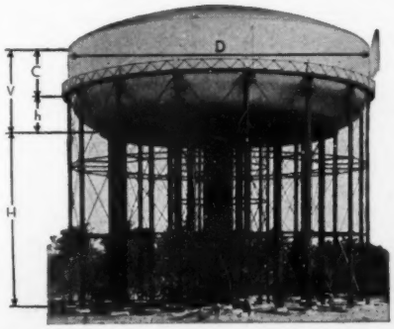


Table V—Toroidal Bottom Tanks



Capacity in U. S. Gallons	Tank Diameter (D) when h = 10' 0" and V = 20' 0" ft.	in.	V = 25' 0" ft.	in.	V = 30' 0" ft.	in.	V = 35' 0" ft.	in.	H
750,000	82	0	73	2	66	8	61	8	
1,000,000	94	5	84	3	76	9	71	0	
1,250,000	105	4	94	0	85	8	79	2	Built to Order
1,500,000	115	2	102	9	93	9	86	8	
2,000,000	132	8	118	5	108	0	99	11	
2,500,000	148	0	132	3	120	7	111	6	
3,000,000	162	0	144	8	131	11	122	1	
4,000,000	186	8	166	9	152	2	140	9	
5,000,000	208	6	186	3	169	11	157	3	

Table VI—Steel Reservoirs

Capacity in U. S. Gallons	Diameter ft.	Height ft.	Height in.
50,000	24	15	1
75,000	24	22	7
100,000	30	19	3
125,000	30	24	0
150,000	36	20	1
175,000	36	23	4
200,000	36	26	8
300,000	42	29	4
400,000	42	39	1
500,000	48	37	5
600,000	60	28	10
750,000	72	25	0
1,000,000	84	24	6
1,500,000	96	28	1
2,000,000	120	24	0
2,500,000	132	24	10
3,000,000	144	25	0
4,000,000	168	24	6

PIPE LINE FRICTION COEFFICIENTS

A Summary of the Findings of the Committee on Pipe Line Friction Coefficients*

The voluminous report embracing data collected and compiled by the above committee has been printed in the September, 1935, *Journal* of the New England Water Works Association, and is available in the form of reprints.

A summary of the scope of this report and the conclusions presented therein are reviewed in the following abstract, prepared by E. T. Killam, chairman of the Committee.

The general conclusions drawn from the data submitted to the Committee are as follows:

1. The average *actual* loss in capacity of tar-coated cast-iron pipe after 30 years of service, based on a total of 473 tests in 19 different systems, was 52 per cent.

The loss *predicted* in the Williams-Hazen tables for mains of similar age and diameter (average 20.5 in.) and for "average soft unfiltered river water" is 32.3 per cent.

2. Based upon the data available to the Committee, the Williams-Hazen age-coefficient relation is applicable primarily to large-diameter mains carrying relatively inactive water.

3. For small-diameter mains carrying active water, the actual *loss* after 30 years may be twice the Williams-Hazen *predicted* loss.

4. Other factors being equal the data show marked correlation between pH value of water carried and rate of capacity loss, average conditions reported indicating for supplies with a pH value of 6.5, twice the loss observed in supplies with a pH value of 8.0.

Scope of Report

The principal objective of the report was the presentation of heretofore unpublished data upon friction coefficients of tar-coated cast iron pipe, with particular reference to the age-coefficient relation for this type of pipe, and the effect of water quality upon rate of capacity loss.

The report also contains sections dealing with various remedial measures for reducing and preventing loss of capacity, including discussions of coefficients of cement and bitumastic-enamel linings; methods of lining pipe in place; corrective treatment of the water carried, and pipe cleaning.

Certain other subjects not involved in the question of discharge coefficients of tar-coated cast-iron pipe, but falling within the general scope of the subject of "Pipe Line Friction Coefficients," have been presented in the form of appendices, in order that this additional information might be made readily available in a single report.

Precision

The Committee has endeavored to compile mass data of reasonable precision; obviously, the widely varying conditions found, and the many factors involved, could not be generalized upon any other basis. Accordingly, while the collection of data was in no way restricted to sources affording "laboratory" precision, the material presented includes only such data as have been considered to fall within the limits of reasonable precision set by the Committee.

This policy of precision applies particularly to the presentation of various "trend curves," which is the designation adopted for expressing the age-coefficient relation. These "trend curves" in which values of C have been plotted against the age of the pipe in years, have been presented only in cases for which numerous tests of reasonable accuracy were available.

In considering these trend curves it should be emphasized that the results represent actual field tests and accordingly include all incidental losses due to irregular line or grade, and due to fittings or special castings.

Use of Williams-Hazen Coefficient "C"

The Williams-Hazen formula has been used throughout the report for the determination of coefficient values, and all values of C refer to the Williams-Hazen coefficient in the following formula:

$$v = C\, r^{0.63}\, s^{0.54}\, 0.001^{-0.04}$$

v = Velocity in feet per second
r = Hydraulic Radius in feet
s = Hydraulic slope in feet per foot
C = The Williams-Hazen Coefficient

In translating values of C to equivalent capacity loss, it is convenient to bear in mind that capacity is directly proportionate to the value of C. With slope and diameter fixed, a drop in the value of C from 130 to 65 consequently involves an equivalent capacity loss of 50 per cent.

Coefficients of Tar-Coated C. I. Pipe

Tar-coated cast iron pipe has been more widely used in water works practice than any other type of pipe, and a discussion of coefficient values with this type of pipe was accordingly selected for the first and principal subject of the report.

In considering the existing condition of old pipe, and attempting to determine the loss of capacity with age, selection of a value of C for new pipe becomes a fundamentally important assumption. The values of C for new tar-coated cast iron pipe adopted in the report are as follows:

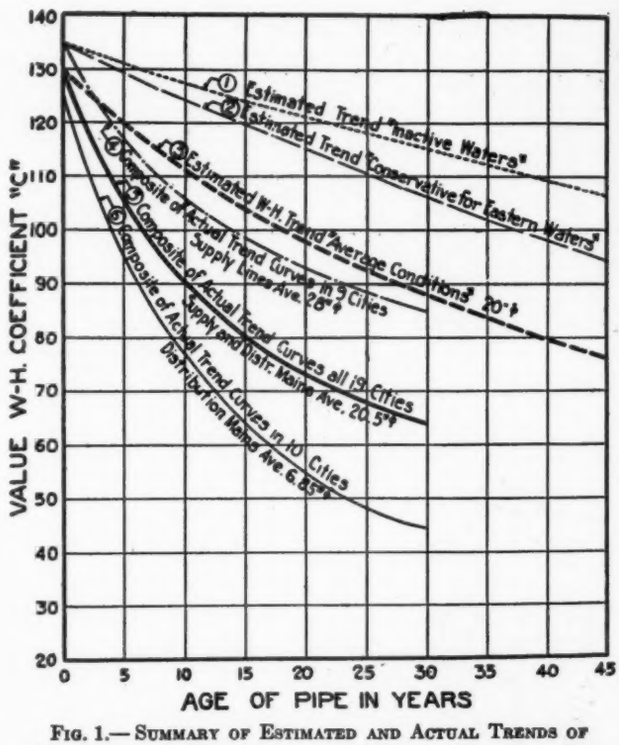


Fig. 1.— Summary of Estimated and Actual Trends of Age-Coefficient Relation for Tar-Coated Cast-Iron Pipe.

***Curves* 1 *and* 2 are based on data for steel pipe (U. S. Dept. of Agriculture, Bull. 150, 1930).**

***Curve* 3 is based on the Williams-Hazen Tables for average soft unfiltered river water.**

***Curve* 4 is a composite for supply and transmission lines 16 in. or larger in diameter.**

***Curve* 6 is a composite for distribution mains less than 16 in. in diameter.**

***Curve* 5 is a composite of Curves 4 and 6. Composite curves are based on arithmetic averages.**

Actual vs. Estimated Losses in Main Capacities with Age Increase Summary Curves Taken from the Report of the Committee of N. E. W. W. A. on Pipe Line Coefficients

*Presented before the New England Water Works Association September 17, 1935.

GENERAL PAINT CORPORATION—Hill, Hubbell & Co. Division

Lining and Coating STEEL PIPE for Water Mains and Supply Lines

CLEVELAND, OHIO

Offices in Tulsa, San Francisco, Los Angeles, Oakland, Portland, Seattle, Spokane

BITURINE AKWALINE Lining Prevents Corrosion, Tuberculation, Incrustation and assures CAPACITY FLOW

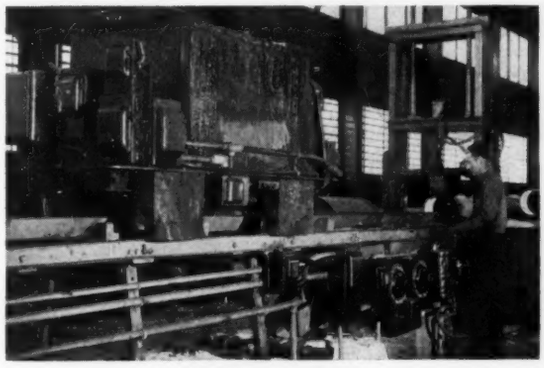
The use of STEEL PIPE for water supply lines is not new! For more than half a century, "big inch" steel pipe has been used—carrying water to many large cities in the United States.

Here are a few of the many inherent and unquestioned supremacies of STEEL PIPE:

Highest bursting strength	Least leakage
Greatest flexibility, ductility	Lowest laying costs
Longest lengths	Greatest, enduring capacity
Fewest joints	Lowest pumping costs

The HILL-HUBBELL Process of applying linings to the more widely used sizes of STEEL PIPE makes it possible for the smaller community, also, to have the many advantages of STEEL PIPE. We line STEEL PIPE from 4½" O.D. to 30" O.D., and coat-and-wrap STEEL PIPE from ¾" Nom. to 30" O.D. Eminent engineers maintain that STEEL PIPE, when Lined inside and Coated-and-Wrapped outside by the HILL-HUBBELL Process, is far more practicable than any other type of pipe.

For ECONOMY and SAFETY—USE STEEL PIPE.



Lining STEEL PIPE

BITURINE AKWALINE Lining in any ferrous pipe prevents tuberculation, corrosion, incrustation, and silting—all of which reduce the original carrying capacity of the pipe. An article on "The Prevention of Corrosion of Pipe" (The American Water Works Association, Volume 16, No. 2, 1936) illustrates the practicability of coal tar lining. Two sections of 6-inch pipe were taken from the Brooklyn System in 1925. One section, laid in 1857, had only one-fifth its original carrying capacity. The other section, laid in 1863, with a coal tar lining, still had, after 62 years of service, its ORIGINAL CARRYING CAPACITY.

In the Hill-Hubbell method, the coal tar enamels are applied, mechanically, in a true multiple coat process. Centrifugal force of the revolving pipe evenly disperses the flow of molten enamel from a slowly withdrawn feed line. The result is a lining of guaranteed minimum thickness and of maximum uniformity. The surface of the lining is as smooth as glass and increases the pipe carrying capacity from 7 to 10% and thereby reduces FOREVER, pumping and operating costs.

Our entire lining application is done AT THE PIPE MILLS, INDOORS. No weather hazards affect the quality of our work. With the most highly developed equipment in the industry to properly handle the coating materials, a Hill-Hubbell job of coal tar enamel lining can not be excelled.

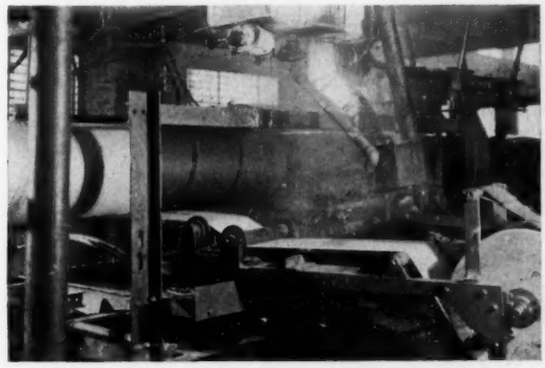
More than 8,000 miles of Steel Pipe have been protected against exterior corrosion by the Hill-Hubbell Process, establishing the unquestioned leadership and acceptance of our method. All our work is done, right in the steel pipe mills, mechanically, indoors—away from all weather hazards.

Proper handling of the coating materials is assured, for we use heating kettles of our own design equipped with positive thermostatic control and tireless mechanical agitation.

Because all bituminous coatings are plastic solids, they need the physical strength given them by shielding reinforcing wrappers. Our method always provides this extra protection, positively bonded to the coating—as it should be.

Because we take pride in our craftsmanship, the final shipping-and-handling wrapper of heavy kraft paper is imprinted with our name. You see our name only on jobs of our Genuine Mill Coating-and-Wrapping.

Mill Coating-and-Wrapping is the modern, proven method of pipe protection.



Coating-and-Wrapping STEEL PIPE

BITURINE AKWALINE PRIMER and ENAMEL

BITURINE AKWALINE Enamel is an all-coal tar pitch enamel developed especially for lining water mains and supply lines. It meets the accepted sagging test at 160° F. and the usual cracking test at —10° F. When your STEEL PIPE is lined with BITURINE AKWALINE Enamel by the HILL-HUBBELL Process, it can not be excelled because the RIGHT enamel is PROPERLY applied. No matter how good the lining is, it must be PROPERLY applied to give 100% protection.

BITURINE ENAMEL

BITURINE Enamel is used for coating STEEL PIPE outside. It is an all-coal tar pitch enamel and has been doing an efficient protection job for over 30 years. BITURINE Enamel, with the additional reinforcement of shielding wrapper, PROPERLY applied at Mills, is now protecting thousands of miles of STEEL PIPE in all parts of the country.

This can NEVER happen to STEEL PIPE lined with BITURINE AKWALINE Enamel

For supply and transmission mains 16 inch and larger in diameter ..... C = 135
For distribution mains less than 16 inch in diameter, with allowance for Ts, valves, bends, corporation cocks, or other specials involving friction loss..... C = 125

Variations possibly approaching 10 per cent higher or lower may be found, but the foregoing represent the average values from data available to the Committee.

The most widely used basis for estimating the probable loss of capacity of tar-coated cast iron pipe with age, (other than the convenient, though inadequate, assumption that C = 100) is the age-coefficient relation shown in the column headings of the Williams-Hazen tables.

These Williams-Hazen predicted age coefficient relations—or trends of C—accordingly form a convenient basis for comparison with actual trends computed from the data submitted to the Committee.

The data compiled on actual trends of the age-coefficient relation for tar-coated C. I. pipe includes a total of 473 tests in 19 different cities. These data, results of which have not heretofore been published, have been classified and are presented in the form of trend curves.

These trend curves, as in the assumption of values for new pipe, have been segregated into two major classifications, namely, for supply and transmission mains 16-inch and over in diameter, and for distribution mains less than 16-inch in diameter.

Further classification has been made by grouping trend curves of similar type or source of supply; or according to general location or type of supply.

Summary of Data on Actual Capacity Loss in Tar-Coated C. I. Pipe

The data on actual loss of capacity in tar-coated C. I. mains may be briefly summarized, as follows:

Supply lines in nine cities showed a loss after 30 years of 37 per cent as compared with a predicted Williams-Hazen loss of 30.8 per cent.

Distribution mains in ten cities showed an actual loss in 30 years of 64 per cent as compared with a Williams-Hazen predicted loss of only 37 per cent.

Average results of 473 tests in 19 individual systems, including sizes ranging generally from 6-inch to 48-inch in diameter, with a weighted average size (according to numbers of tests of each size) of 20.5 inches, showed an actual loss in 30 years of 51.5 per cent, as compared with a predicted loss of 32.3 per cent for pipe of the same diameter.

These data accordingly indicate that the Williams-Hazen predicted trends are applicable primarily to large diameter mains carrying relatively inactive water—and do not represent "average conditions."

Quality of Supply and Its Effect on Capacity Loss

The wide variation in rate of capacity loss in different systems and the appreciable extent to which this loss progresses in a relatively short time in many systems, directs attention to probable causes of such loss. In collecting data, the Committee has accordingly attempted to consider the quality of supply and its effect upon rate of capacity loss.

Alkalinity and carbon dioxide have an important effect on rate of capacity loss. Because of the inter-relation between alkalinity, carbon dioxide, and pH, this effect may be measured against the pH value alone.

The relation of pH to rate of capacity loss has been illustrated in the report by a diagram on which the per cent of capacity loss in a fixed period, (30 years) in various supplies, has been plotted directly against the pH of the supply.

The pronounced relation indicated by the data, showing the marked effect of pH on the relative rate of loss, may be summarized as follows:

pH Value of Supply	Approximate Average Per Cent Capacity Loss in Tar-Coated C. I. Pipe (In 30 Years)
8.0	30
7.5	35
7.0	45
6.5	60
6.0	85

Capacity Loss in Tar-Coated C. I. Pipe Due to Special Causes Other Than Tuberculation

Although tuberculation is most frequently the cause of loss of capacity in tar-coated cast iron mains, certain cases included in the Committee data afford examples of capacity loss due to other special causes. In some instances the resulting trends of capacity loss are quite similar to cases where loss was caused by tuberculation. Among special causes of capacity loss are: incrustation, due to the precipitation on the pipe either of natural mineral content in the water, or of lime after water treatment; slime or fungus growth; and silting.

Coefficient Values of Cement-Lined Pipe

In addition to the main section of the report dealing with friction coefficients of tar-coated cast iron pipe, a number of related subjects involved in the general question of friction coefficients, are discussed.

Accordingly a second section of the report is devoted to coefficient values of cement-lined pipe.

The development of the centrifugal method of applying cement lining has inevitably resulted in the increased use of this type of lining as a method of preventing capacity loss. Available data upon the values of C for cement-lined pipe are limited in scope and widely scattered in the literature. Accordingly, all available data have been compiled and presented in order that they may be made more readily available.

The Committee data indicates that the average value of C for new pipe, 4-inch to 24-inch in diameter with cement lining centrifugally applied, is 134, based on nominal diameter; and 150 based on actual net diameter.

These data also indicate that at least for mains 24-inch or less in diameter, the effect of lining thickness on diameter encroachment is sufficient to warrant considering values of C based both on nominal and on actual net diameter.

Other tests on pipe with cement linings not applied by centrifugal methods showed the following values: For pipe with natural or Rosendale cement lining tested both when new and at the end of approximately a 10-year period, C = 136; for old style cement lined wrought-iron pipe 12-inch and 14-inch diameter, after 41 years of service, C = 104.

Available data relative to the value of cement lining in maintaining hydraulic capacity are extremely limited in scope. One line tested when new and again after six years of service showed no loss of capacity. Another line tested when new and after 1, 7, and 10 years of service, also showed no tendency to decrease in carrying capacity with age. The data indicate that cement lining can be credited with a sustained capacity not attainable with tar-coating.

Coefficient Values of Pipe with Bitumastic Enamel Lining Centrifugally Applied

A third section of the report is devoted to a discussion of coefficient values with Bitumastic enamel lining applied by the centrifugal method. As in the case of cement lining, development of centrifugal methods of application have resulted in a greatly increased use of this type of lining to control capacity loss. Due to limited data available, results of all of the tests which have been conducted, together with a discussion of test methods, have been presented in the report. Results available include tests on 10, 12, and 20-inch cast iron pipe; and on 30-inch steel pipe.

The data indicate that coefficient values for new supply and transmission mains 16-inch in diameter and larger, with bitumastic enamel lining (centrifugally applied) may vary from C = 145 to C = 160 with an average value of C = 155; all based on nominal diameter.

These data also indicate that coefficient values for distribution mains less than 16-inch in diameter, with this style of lining, may vary from C = 140 to C = 150 with an average value of C = 145.

Bitumastic enamel lining is ordinarily applied with a thickness of only 3/32-inch. Encroachment on diameter is accordingly small, as compared with other types of lining.

The first application of this type of lining was in 1931, and accordingly no data is available relative to its effectiveness in sustaining hydraulic capacity. The longest service period reported is two years, and the results of this test indicate no loss. The same material applied by the hand-brush method has been widely used for many years, and visual inspection of large pipe thus lined indicates that at least within periods of 16 years no apparent deterioration has occurred.

Application of Linings to Mains in Place

While the foregoing methods of lining pipe provide methods of preventing or retarding capacity loss on new work, the question of restoration of capacity of many miles of mains already in place is of no less importance. The high cost of

abandonment and duplication of existing mains, particularly under permanent pavements has directed attention to possible methods of reconditioning or lining existing mains in place, subsequent to cleaning.

Reference is made in one section of the report to available methods of lining mains in place.

Two methods have been devised in England for lining small diameter mains; the "Eric" process by which a bitumen lining is deposited electrically; and the Tate process, by which a cement-mortar lining is deposited in the pipe.

In this country, two methods have been developed for the reconditioning and lining of large diameter mains. On pipe lines sufficiently large to permit entry, the lines may be carefully cleaned and then treated with an application of hot bitumastic lining. A second method, which has recently been developed, involves the centrifugal application of a cement lining to large diameter mains in place. The lining is whirled into place by centrifugal force from a high speed centrifugal jet.

Corrective Treatment

In addition to the use of protective linings, chemical treatment of the water for reduction of corrosion has been adopted in recent years to abate the problem of capacity loss, and mention is made in the report, of some of the more important phases of corrective treatment.

Lime, sodium hydroxide and soda ash are among the alkalies used to reduce corrosion.

If water is maintained saturated with respect to calcium carbonate, it will be practically non-corrosive to iron.

In maintaining adequate corrective treatment it is essential to maintain the treated water at or very near the saturation point, for super-saturation results in excessive deposits, and under-saturation causes the destruction of the needed protective film.

In corrective treatment, consideration must be given to the fact that the pH value at which saturation equilibrium occurs, varies with the characteristics of the water treated.

The calcium bi-carbonate, (alkalinity) of the water and its magnesium content are the most important factors. Saturation occurs at a pH of only 7.2 with an alkalinity of 190 ppm., whereas with water containing only 15 ppm. alkalinity, the pH must be raised to 9.3.

Accordingly, in planning corrective treatment, particular attention must be given to the characteristics of the water. The fact that a pH of 8.0 for example, is successful in controlling corrosion in one system, is no criterion as to the pH that must be maintained with another supply.

Restoration of Capacity of Unlined Cast Iron Mains by Cleaning

Cleaning of cast iron mains to restore capacity is an important consideration in the problem of capacity loss.

Two important phases of this question are discussed in the report: First, the immediate increase in coefficient values and consequent increase in capacity obtainable by cleaning. Second, the rate of capacity loss subsequent to cleaning, or otherwise expressed, the maintenance of capacity after cleaning.

Data available to the Committee indicate that cleaning will ordinarily restore mains to approximately 85 per cent of their original capacity. The average value of C in 24 tests was 39 before cleaning, and 104 after cleaning. If it is assumed that the value of C for new pipe was 125, the percentage of original capacity was accordingly 31 per cent before, and 83 per cent after cleaning.

The period through which the relatively high capacity obtained immediately after cleaning is sustained, is subject to wide variations in individual cases. Some instances, particularly with small mains, are recorded, wherein the results of cleaning do not last more than four or five months. In other instances the capacity is maintained at reasonably high values for substantial periods of time.

Summary of Appendices

All of the foregoing subjects deal directly with coefficents with tar-coated cast iron pipe, with the effect of age on coefficient values, or with alternate methods of retarding or preventing capacity loss.

Certain other subjects, while not directly concerned with these questions are, nevertheless, involved in the general questions of pipe-line friction coefficients. Among these related subjects are coefficient values of steel and of concrete pipe.

Coefficient Values of Steel Pipe

A discussion of coefficent values for steel pipe, due to the wide difference in interior surface with various methods of pipe construction, necessitates a definition of the several classes of steel pipe.

The classification of alternate types by Scobey in Bulletin 150 of the U. S. Dept. of Agriculture, provides a convenient standard for summarizing the values of C for various types of steel pipe when new.

The ordinary average values of Williams-Hazen C for various classes of new steel pipe may be summarized as follows:

Corrugated pipe	60
Spiral riveted flow against laps	100
Spiral riveted flow with laps	110
Full riveted	115
Girth riveted	130
Continuous interior pipe	139

Coefficient Values of Concrete Pipe

Available data on concrete pipe indicate an extremely wide range in values of C, with instances of values as low as $C = 85$ and as high as $C = 152$. This wide range may be attributed not only to variation in surface texture or roughness of the pipe, but also to the relative uniformity of the pipe bore or, in other words, the presence or absence of undulations on the interior surface.

With these wide variations, particular care must be exercised in selecting values of C for concrete pipe.

Data available to the Committee indicate that the average value of C for the best grade, new, and large diameter precast reinforced concrete pipe, carefully manufactured, may be assumed to approximate $C = 150$. On the other hand unless rigid metal forms, rich mix of concrete, careful curing and best workmanship throughout are employed, considerably lower values must be anticipated.

Values of C for concrete pipe of different classes and different methods of manufacture are presented in the report, these values being taken largely from a comprehensive paper by Fred C. Scobey, on this subject.

Tests on concrete pipe after substantial periods of service indicate that under normal conditions the initial capacity is relatively permanent.

Summary

The vast financial loss resulting from rapid capacity reduction of pipe systems indicated by the data upon which the report is based, is a matter of major importance to the water works industry. It is believed of sufficient moment to warrant the determination, in each system, of the rate and cause of loss; as a basis for the adoption of the best preventive measures whether they are provision of permanent linings or corrective treatment of the supply.

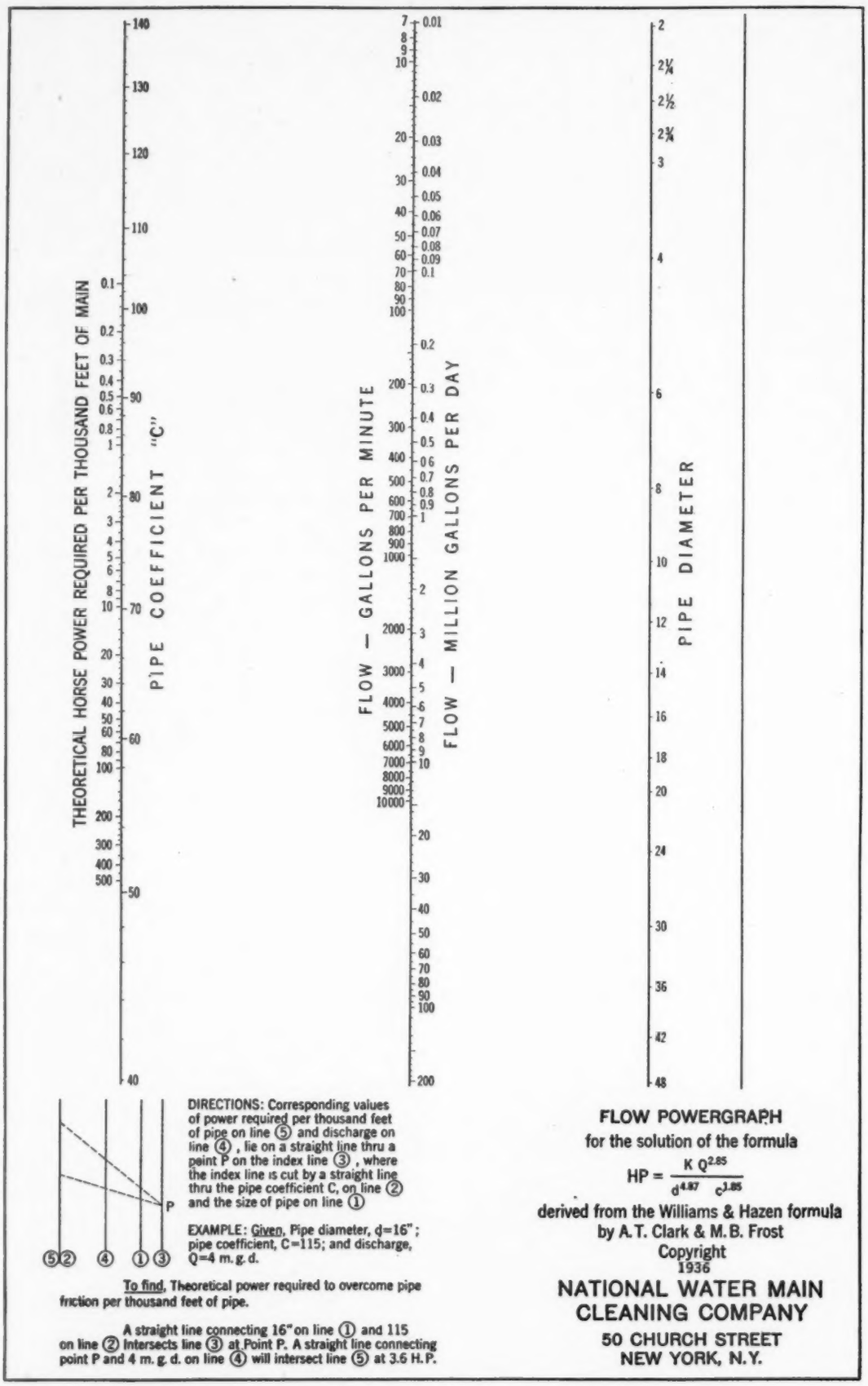
Upon the basis of the average data on tar-coated cast iron pipe, it is found that in 19 cities the average value of C after 30 years' service was 64, as compared with a value of 88 predicted in the Williams-Hazen tables. Otherwise expressed the value of C dropped to 88 after only 11 years of service instead of after a predicted period of 30 years.

Furthermore, these average figures involve relatively large mains (20.5 inches average diameter). In 8 out of 10 systems the value of C for distribution mains after 30 years' service was less than 50—involving a consequent loss of capacity of from 61.6 to 84 per cent, as compared with a predicted loss of 37.5 per cent.

The trend curves presented in the report, illustrate a wide range of loss of capacity in various systems, and the very considerable magnitude to which such loss develops within a comparatively short period in relation to the structural life of the pipe. It is hoped that these curves will serve to interest members of this and other associations in conducting and recording tests, in order that more selective numerical data may be ultimately made available to the profession.

Elson T. Killam, Chairman; Frank A. Barbour, W. W. Brush, Laurence C. Hough, Charles W. Sherman.

Flow Powergraph


THEORETICAL HORSE POWER REQUIRED PER THOUSAND FEET OF MAIN
PIPE COEFFICIENT "C"
FLOW — GALLONS PER MINUTE
FLOW — MILLION GALLONS PER DAY
PIPE DIAMETER
DIRECTIONS: Corresponding values of power required per thousand feet of pipe on line ⑤ and discharge on line ④, lie on a straight line thru a point P on the index line ③, where the index line is cut by a straight line thru the pipe coefficient C, on line ② and the size of pipe on line ①
EXAMPLE: Given, Pipe diameter, d=16"; pipe coefficient, C=115; and discharge, Q=4 m.g.d.
To find, Theoretical power required to overcome pipe friction per thousand feet of pipe.
A straight line connecting 16" on line ① and 115 on line ② intersects line ③ at Point P. A straight line connecting point P and 4 m.g.d. on line ④ will intersect line ⑤ at 3.6 H.P.
FLOW POWERGRAPH
for the solution of the formula
HP = K Q^2.85 / d^4.87 C^1.85
derived from the Williams & Hazen formula
by A.T. Clark & M.B. Frost
Copyright
1936
NATIONAL WATER MAIN CLEANING COMPANY
50 CHURCH STREET
NEW YORK, N.Y.

This Highly Useful Graph Was Devised by Arthur T. Clark and M. B. Frost for Simplified Determination of Power Required to Overcome Pipe Friction Under Various Conditions. Also to Determine Condition of Pipe Lines in Service. (Copies of This Graph on Linen Are Being Distributed Gratis by National Water Main Cleaning Co., New York City.)

EXPERIENCES IN WATER MAIN CLEANING

By CHARLES STREITHOF

Genl. Supt., Dept. of Water Works, Evansville, Ind.

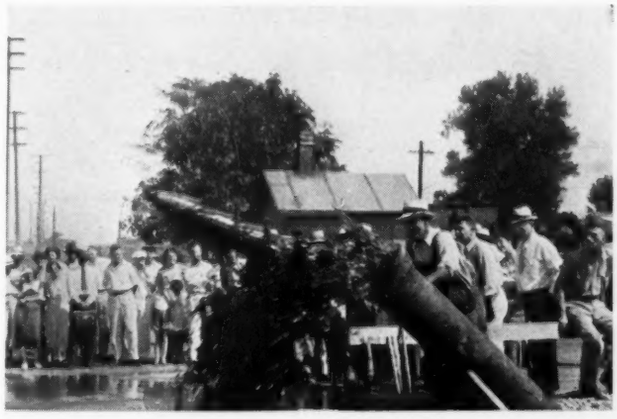
Before the Indiana Section of the American Water Works Association, I had the pleasure of presenting a paper entitled, "Inserting Gate Valves Under Pressure." (See WATER WORKS AND SEWERAGE—June, 1934.)

After the valve inserting job was completed, having seen the condition of our important mains, I felt justified in asking for an appropriation, to start cleaning some of the mains. I was able to convince our Board of Water Works Trustees of the necessity for, and the importance of, this work. It was decided to at least clean some of the larger and older mains; and, a contract was made with the National Water Main Cleaning Company of New York City, to do the cleaning.

The cleaning was started on six thousand (6,000) feet of 16-inch pipe and was continued until the contract was completed. Under the contract a total of 37,956 feet of 12, 16 and 20-inch mains were cleaned, and practically restored to their original carrying capacities. The results obtained were so gratifying and satisfactory that the Water Works Trustees were thoroughly convinced of the advisability of continuing this excellent work. A second contract was made with the same company to clean all mains of 10 to 30-inch diameters which had been laid prior to filtration. The total length of mains cleaned under the second contract was approximately 87,500 feet, and the results obtained were as good as, if not better than, those of the first contract. The Board of Trustees then decided that it would be wise to clean all pipes laid prior to filtration, and a third contract was made with the same company, to cover approximately 450,000 ft., which included principally 6 and 8-inch pipe.

Cleaning Procedure

The preparations and cleaning operations are simple, yet most effective. The section of line to be cleaned is "killed" by closing two valves, one nearest the inlet, for the entrance of the cleaning apparatus, and the other nearest the outlet. At the inlet end, the pipe is exposed and a piece of the main, about 6 ft. long, is removed and cleaned by hand. The cleaning device (sometimes called the "rabbit") is placed in it, and the section is then returned permanently to the line by employing a sleeve or coupling and using the bell end of the existing pipe. At the outlet the line is also exposed, where a smaller piece is removed, depending on the diameter, so as to permit a 45-degree bend of the same size to be attached to the end of the line to be cleaned. This joint is made with yarn only. And to the 45-degree bend is added a short piece of pipe, jointed with yarn also, to bring the line up to, and a little above, the level of the street. Then the valves controlling the lines leading off from the one to be cleaned are closed. Likewise all curbcocks are closed. It is now time to start the cleaning apparatus on its journey. The valve nearest the inlet is opened. The water entering the dead line hits the cleaning machine and as the pressure and volume increase, the machine starts to move, and if there is no obstruction in the line, such as a partly closed valve or large pieces of lead from a poorly poured joint, the machine will travel the entire length of the line to be cleaned and come out on to the pavement at the 45-degree outlet. The rate of travel is never alike in any two pipe lines of the same size and length. In cleaning 8,257 ft. of 30 in. pipe the cleaning machine traveled at a speed of 60 ft. per minute and discharged 47 truck loads of mud, not counting that which went into the sewers.



An Increasing Interest Is Shown in Cleaning Water Mains. This Job Was at Evansville, Ind.

Ample Evidence That Evansville's Mains Needed Cleaning

While the machine is moving, enough water passes it to serve as wash water, which helps to reduce the pressure of the material ahead of the machine, and long before the appearance of the machine, some of the obstructing material will be seen on the pavement. Almost from the moment that machine starts to move from the inlet end, until it is out of the main, the wash water which precedes it is very dirty. Immediately following the appearance of the machine at the outlet the water practically clears up, but it is advisable to permit the water to run a short time to thoroughly flush the line. When the machine has done its job, and the line has been flushed, it is a simple task to remove the makeup at the outlet, replace the piece of pipe there, open the valves which had "killed" the line and then those controlling the side lines, and finally the curbcocks.

Result of Cleaning

The results from main cleaning at Evansville were most gratifying. Velocity tests were run on various lines before cleaning, and the drop in pressure noted, as well as the discharge at the hydrants. The same hydrants were used after the mains were cleaned, and when the readings were taken, the difference showed an increase of 15 to 35 per cent in the water discharged. With two hydrants discharging 1,000 gallons per minute each, a drop of but two to four pounds was noted, whereas before cleaning a drop of six to fifteen pounds was common.*

In addition, practically all the valves in the pipe lines were operated and tested, and those found defective were repaired or replaced. The customary annual inspection of valves is not necessary on the lines which have been cleaned, because of the very thorough job done in conjunction with the cleaning program.

Under the three contracts 506,129 ft. of pipe were cleaned as follows:

Diam.	Feet	Diam.	Feet	Diam.	Feet
30-in.	10,725	24-in.	2,196	20-in.	13,563
16-in.	30,238	12-in.	43,007	10-in.	4,609
8-in.	65,206	6-in.	324,350	4-in.	12,236

The cost was:

Contract cost	$55,700.52
Labor furnished by water department	27,881.22
Material furnished by water department	10,329.30
Repairing paved streets	5,330.41
Total cost	$99,241.45

[*Recently a 48-inch intake main 2000 ft. long under 30 ft. of water was successfully cleaned of 8 tons of tuberculated material at Erie, Pa., to raise the coefficient from C = 57 to C = 87 and yield of 23 m.g.d. raised to 35 m.g.d. It represented a new experience in main cleaning.—Ed.]

The average cost was 19.6 cents per foot of pipe (all sizes) cleaned.

Average material cost was 3 cents per 100 ft., which included paving, pipe, lead and yarn, repairing old valves and new valves where necessary.

During the pipe cleaning, the question was often asked: "How did all the mud get in the pipes?" The answer is this: The first water works was built in 1873 and took the supply direct from the Ohio River and pumped it into the pipe system without any settling or filtering.

In 1912 when the present filter plant was placed in operation, every effort was made to flush the mud out of the pipe lines but without success. On account of lack of funds the pipe cleaning job was delayed.

The question has been asked: "How did you pay for the pipe cleaning job?" The answer is this: The Water Department has always made a nice profit but in order that our books will show no loss when making such a large expenditure at one time, a "Deferred Charge" scheme has been instituted in order to spread the costs over a period of 10 years. However, understand, the Water Department payed all of the bill in cash—the "Deferred Charge" being only a matter of bookkeeping to spread the cost out.

USE OF INHIBITORS IN CLEANING METALLIC PIPE

By ALLEN ABRAMS* and C. L. WAGNER*

Rothschild, Wis.

Water pipes in certain sections of the country are likely to become clogged by corrosion or deposits from the water. In many cases this has required replacement of the pipes, a procedure which is often costly due to the necessity of tearing out walls and floors. As a result there have been attempts to clean pipes by the use of muriatic or other acids with the intent to leave the acid in just long enough to remove the scale and yet not long enough to attack the pipe itself. This, however, is a questionable expedient and may be more expensive than the replacement of the pipes.

During the last decade considerable interest has been shown in the use of inhibitors in pipe cleaning operations involving acid treatment. These are usually nitrogenous materials such as aniline or pyridine; and, even glue and flour have been used. When small quantities of such substances are added to an acid solution the resultant mixture will attack rust or scale but will have practically no effect on the pure metal itself. Wide use has therefore been made of this principle in the acid process of "pickling" metals to effectively remove scale while rendering the loss of metal underneath almost negligible.

An example is also given of the use of this principle in cleaning the pipes of a thirty-five story office building located in downtown New York.[1]

Many of the pipes were concealed behind expensive marble walls and it was estimated that it would cost between $100,000 and $300,000 to replace this piping, not to mention the serious inconvenience to tenants. By the use of an acid-inhibitor combination the whole cleaning operation was carried out on Saturday afternoon without inconvenience to the tenants. The pipes were returned to practically their normal condition of carrying capacities and the cost of the operation was but nominal.

This method attracted our attention in 1927 and we made initial tests to determine how effectively inhibitors would reduce the action of acid on the metal. In parallel tests on galvanized iron pipes 16 per cent muriatic acid was used alone, to compare with the same acid containing 3 per cent of an inhibitor. Equal lengths of pipe were allowed to stand in each solution for six hours. At the end of that time the pipe in muriatic acid had lost 50 per cent of its weight while that in the inhibited acid had lost but 0.2 per cent of its weight. We were then satisfied that the inhibitors would effectively prevent destruction of the pipes by such acid when submerged for a relatively short period.

Working Demons Fractious

Not long afterwards two lengths of pipe, leading from the basement of our main office to the second floor became filled with rust and other deposit, completely stopping the passage of steam. It would have been relatively expensive to replace this piping and we therefore opened the two lengths at the top and cleaned them by pouring in inhibited acid, allowing it to work its way through. One overnight treatment, followed by a thorough flushing was sufficient to clean these pipes and no further trouble was encountered.

Early this year the Marathon County Board decided that it would be necessary to tear out and replace all the water piping in the Mount View Sanatorium due to the fact that it was so stopped up that it was impossible to get an adequate water supply through the system. When the matter was brought to our attention we suggested that an attempt be made to clean several lengths of this pipe and a decision could then be made as to the further course to be pursued.

Twenty-five gallons of 14 per cent muriatic acid were treated with 3 per cent, by volume, of the inhibitor.†† The treated acid was placed in a barrel to which was connected the suction of a small rotary pump. The acid was then forced upward from the basement to the second floor through a length of one-inch pipe, thence through a cross-over and down through another length of pipe to the basement. The returning acid passed through a fine screen to remove any dislodged particles and thence to the solution barrel.

At the beginning of the test a considerable amount of solid material was dislodged from the pipes and it was almost impossible to force the acid through. The pipes were then opened on the second floor, the acid mixture was poured in and allowed to flow by gravity until the pipes were filled. The bottom openings were plugged, the acid allowed to stand for eight hours and the acid withdrawn and the pipes thoroughly flushed. Examination indicated that the scale had been practically completely removed.

Control Procedure

In order to determine how effectively the cleaning was being done, three 6-inch lengths were cut from a 1-inch pipe, which was so clogged with rust and dirt that it was barely possible to get a pencil into the opening. One of these pipes was retained without treatment and the other two were connected in the circuit through which the acid was being pumped. At the end of about two hours one length of pipe was removed and found to be almost completely clean except for small patches of rust on the walls. After ten hours the other length of pipe removed for examination proved to be entirely free of rust and scale and there was no apparent action on the metal itself.

In the cleaning operation approximately 2,800 feet of pipe were treated, ranging from ½ inch to 4 inches in diameter. Estimates by George Baumgardt, who was in charge of the plumbing work, showed that the total labor costs were $870, while the cost of acid and inhibitor was approximately $20—a total of $890. Mr. Baumgardt estimated that the cost of replacing the piping would have been:

Galvanized pipe fittings and valves	$1,000
Labor for installation	5,000
Plaster, concrete floor and repainting	2,500
Total	$8,500

*Department of Research and Development, Marathon Paper Mills Co., for which the senior author is Technical Director. Mr. Wagner is chemist.

[1]"Removing Rust from a System with Piping Acid," F. N. Speller, E. L. Chappell and R. P. Russell—Chem. and Met. Engineering, July, 1927.

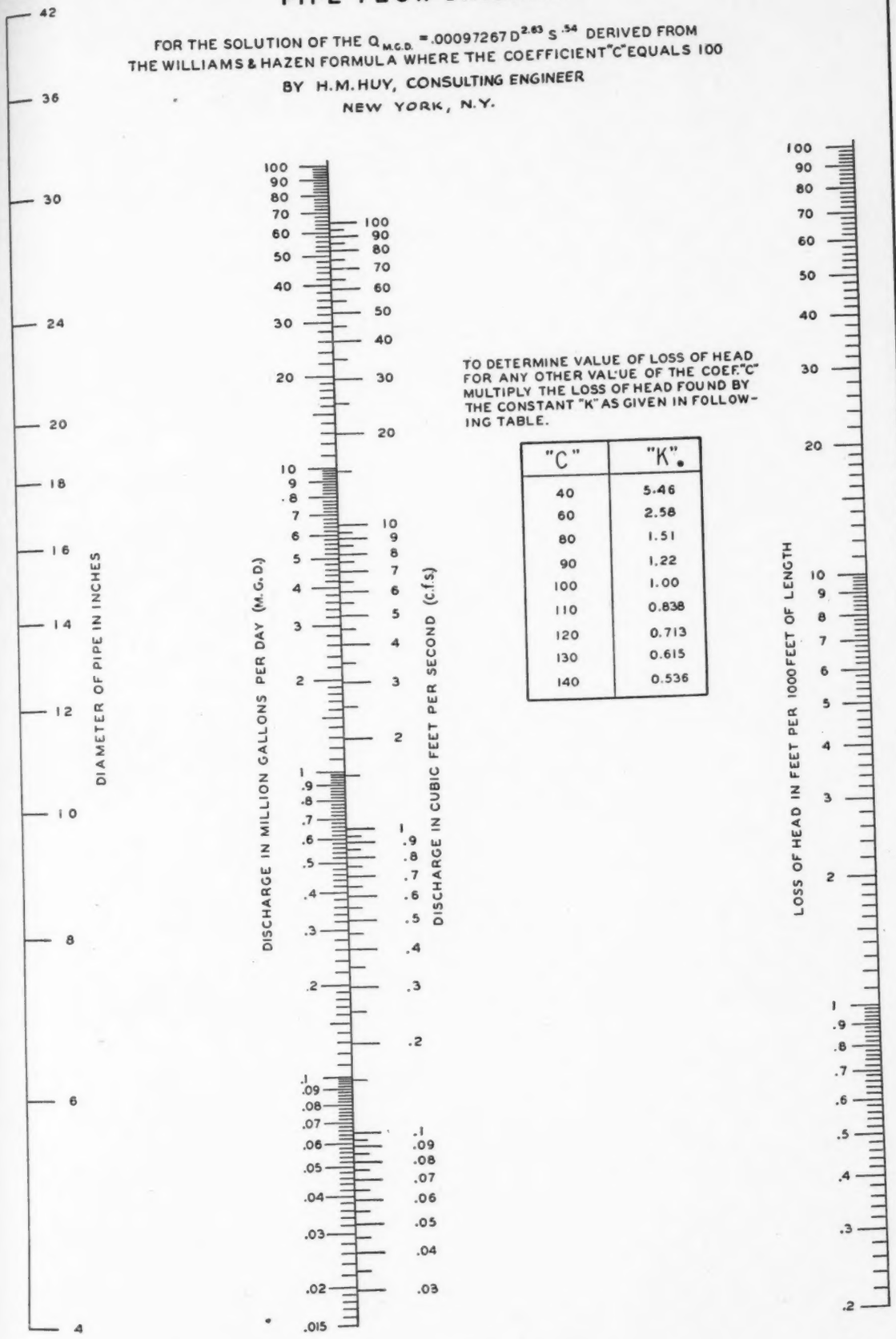
††Inhibitors are available, from several of the larger chemical companies—Barrett & Co., Monsanto Chemical Co., General Chemical Co., et al.

PIPE FLOW DIAGRAM

FOR THE SOLUTION OF THE $Q_{M.G.D.} = .00097267\,D^{2.63}\,S^{.54}$ DERIVED FROM THE WILLIAMS & HAZEN FORMULA WHERE THE COEFFICIENT "C" EQUALS 100

BY H.M. HUY, CONSULTING ENGINEER

NEW YORK, N.Y.



TO DETERMINE VALUE OF LOSS OF HEAD FOR ANY OTHER VALUE OF THE COEF. "C" MULTIPLY THE LOSS OF HEAD FOUND BY THE CONSTANT "K" AS GIVEN IN FOLLOWING TABLE.

"C"	"K".
40	5.46
60	2.58
80	1.51
90	1.22
100	1.00
110	0.838
120	0.713
130	0.615
140	0.536

(b) FRICTION COEFFICIENT "C": Determine hydrant discharge rate (M.G.D.) at the end of a section of pipe line. Take simultaneous pressure readings at non-flowing hydrants on the same line several hundred feet ahead. Correct all pressure readings for difference in elevations of gages and calculated friction head loss per 1,000 ft. of intervening pipe*. From flow rates observed and known pipe diameter, follow Example (a) to obtain loss of head which would have resulted with coefficient at "C100." This figure divided into the actual (observed) loss of head reveals the "K" factor and from the useful "C-K" table the coefficient "C" can be approximated. *(Accuracy depends upon the use of tested pressure gages, careful flow measurements, and inducing a large loss of head between the non-flowing hydrants. For procedure in making hydrant flow tests, see article by Wilson elsewhere in this Section.)

PIPE FLOW DIAGRAM (HUY)

(a) FRICTION-HEAD LOSS: A line run from pipe diameter (left vertical) through M.G.D. rates of flow (center) intersects friction vertical (right) to reveal computed friction loss per 1,000 ft. of pipe line; or pressure required per 1,000 ft., in pumping, to overcome such loss due to friction at corresponding line capacity. (If the friction coefficient, due to greater roughness or smoothness of the pipe walls, is other than the base used ["C=100"] multiply the head loss obtained by the corresponding "K" factor given for various "C" values in the "C-K" table on the chart.)

Directions for Application of This Diagram

(This diagram is reproduced through courtesy of H. M. Huy and permission of Hydraulic Development Corp. At a location earlier in the reference and Data Section, P. S. Wilson describes Practical Methods of Making Flow Tests at Hydrants.

COMPRESSED AIR FLUSHING OF SMALL MAINS*

By R. F. BROWN

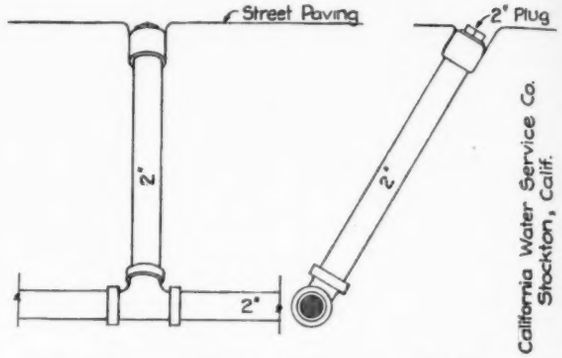
Plant Manager, California Water Service Co., Stockton, California

R. F. Brown

Many water systems in the older California towns, like Topsy, just grew without any suggestion of planning for the future. Stockton was no exception. As a consequence we found ourselves with a great many 2-inch lines in the thinly populated areas.

We have for many years followed the practice of flushing small mains and all dead ends regularly by opening fire hydrants and flusher valves and simply allowing the water to flow from the main under normal pressure of 45 pounds until the main is apparently clear. Under this program all dead ends and all small mains are given ordinary flushing, approximately at intervals of every two months.

This method, however, does nothing but freshen the water in the dead ends and small mains. In order to effect a more lasting cure for taste and odor complaints, we decided to try boosting the pressure in the main with air to attempt to break loose more of the troublesome algae and other deposited material that attaches to the pipe wall. All of our dead ends, regardless of size, and at least every other block of our 2-inch lines have what we call flusher-risers installed for the convenience of our periodical flushing program—see sketch.



RISER CONNECTION TO 2" MAIN FOR FLUSHING

Air Flushing Operations

Compressed air is put into the line through a service connection midway between two flusher-risers after we have first closed the shut-off valves on the intervening services. The valve on the flusher-riser is then opened. All water in the line is forced out through the riser, by air under 90 pounds pressure. As soon as the air has expelled all the water from the line it is shut off and water under our ordinary pressure is run through the line to sweep out, through the flusher-riser, all particles of scale, sand or foreign matter that have been loosened by the air "shooting." We proceed in this manner alternately turning into the line air under 90 pounds pressure and water at 45 pounds until the flushing water leaving the risers no longer carries with it any scale or other foreign matter.

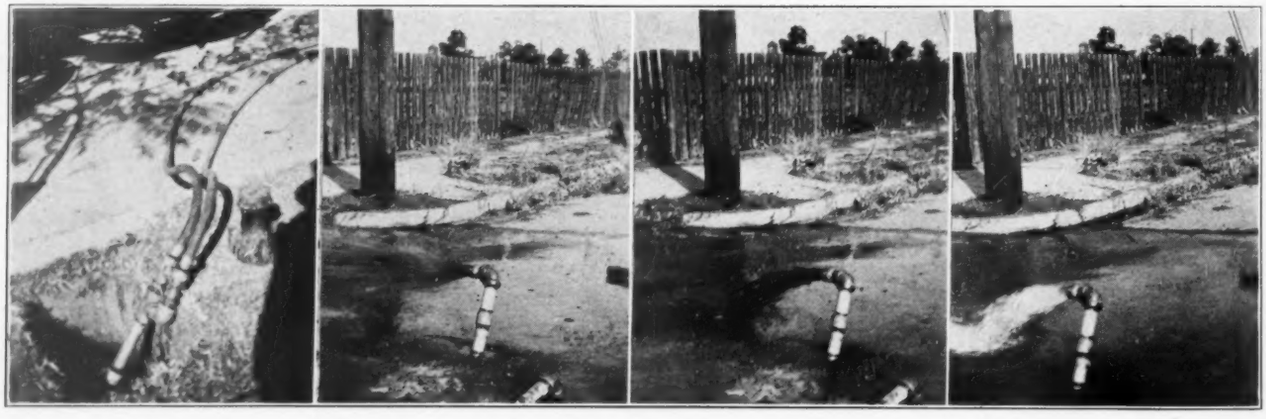
This system is apparently successful in accomplishing our purpose and it is economical, because the equipment required is only a portable air compressor and an air storage tank to provide a volume of air under pressure. No expensive cutting of mains or pavement is required and most jobs can be handled with a three-man crew.

When we first started this system we cleaned 40,000 feet of line, mostly 2-inch, over a period of two months. The cost was from 60 to 90 cts. per hundred feet, depending upon the number of services which had to be shut off and turned on again.

The success of this method of flushing is measured by the almost complete absence of the usual recurring taste and odor complaints from consumers served by mains thus treated. It is problematical how soon we will have to repeat this treatment, because from no consumer on the first line so treated has there yet developed a recurrence of complaints.

A secondary result, not anticipated, is the increase in carrying capacity of the 2-inch lines brought about by the loosening and blowing out of a great deal of scale. Thus has resulted a reduction in complaints of poor pressure as well as the taste and odor complaints.

A Self-Told Story



Air Lines Connected (This Time Through House Service at Curb Line)

First 90 Lb. Air Shot. (Note Extension Attached to Flushing-Riser)

First 45 Lb. Water Flush. (No Argument About Need to Eye or Nose)

Clear Water (Shooting and Flush Repeated As Indicated)

*From WATER WORKS AND SEWERAGE, April, 1937.

BLOWING OUT SERVICE LINES*

By S. H. DAVIS

Superintendent, Benwood & McMechen Water Co.
Benwood, W. Va.

Most every water works operator will agree that a low pressure complaint can cause a water company to have poor, or at least "razor-edged," public relations between the affected customer and the company.

However, unless the condition is caused by insufficient main line capacity, the consumer's line, as well as the company's service line, is usually the cause of the low pressure complaint. Attempts to convince the affected customer that he should renew his lines usually brings the following question or statement: "Suppose I do renew my lines, maybe your line is stopped up between the main line and my property. How about you people doing a little digging first?" To answer that question to his satisfaction, usually means to remove meter, if located at property line or curb plot, or cut service line at curb-stop, and let him see for himself. If the pressure is poor and he sees it, he becomes very positive that he won't spend a dime until given better water pressure. He thinks it is high time that the water company correct that condition and he wants it done *"right now."*

Naturally, anyone responsible for the operation of a water company wants the customers satisfied, but on the other hand, he hates to dig into a paved street to disconnect a service from the corporation, or to renew the service line to satisfy the customer.

Method of Cleaning

We have had the usual number of low pressure complaints with all the grief that goes with them. We have tried various methods of cleaning out service lines and the method we now use is the compressed air and rock salt method.

The equipment consists of the following parts:

(1) Cylinder of compressed air—*don't use oxygen.*
(2) 15 ft. (2,000-lb.) wire braided hose with suitable connections to connect to service line.
(3) 1 (2,000-lb working pressure) check valve.
(4) 1 (2,000-lb.) working pressure) forged cross tee.
(5) 1 (2,000-lb. working pressure) angle valve—wheel type.
(6) 1 (1,000-lb.) relief valve—set at 600 to 800 lbs.
(7) 1 (1,800-lb.) pressure gauge.
(8) Necessary nipples to connect fittings and for connections on air cylinder (use extra heavy nipples).

The method of blowing out service lines is as follows:

(1) Make necessary test for low pressure.
(2) Fill wire braided hose with about 2 ft. of coarse rock salt (ice cream salt) and connect to service line with curb or meter stop in the off position.
(3) Close angle valve on tank connection—hose.
(4) Open curb or meter stop.
(5) Just crack needle valve on compressed air tank and then close *quickly* with one hand.
(6) Open angle valve *immediately* with other hand—the "shot" is fired.
(7) Allow muddy water from service to blow through angle valve until water is clear.
(8) Connect up line.

It is advisable to "crack" a nearby fire plug so that the excess air will go out through plug.

The action of the compressed air is very quick and a surging will be noticed in the armored wire hose, but after a few seconds the surging will stop and the water will flow out of the angle valve with normal pressure. As the rock salt enters the service line it literally scrapes the incrustation away from the line and the rock salt dissolves in the main line. No complaint of salty taste in the water has resulted, however.

This system is only recommended where lead or copper service lines have been installed. There is too much danger of rupturing a weakened steel line which is badly corroded.

The photographs show the results of this method. The height of water above ½-inch riser pipe (30 in. above curb stop) was 3 in. only. But, after blowing out service line the height of water was 36 in., indicating increased pressure and volume obtained.

We have found that after we do our part, should the pressure continue low, consumers become convinced that their piping is either corroded or too small. In most cases they will remedy their condition. We do not blow service lines from cellar to property line, because we feel that is the plumber's job.

The average time required to attach the equipment and blow out a service line is only 15 minutes. Our cost for a cylinder of air is approximately $2.50.

*An article published in WATER WORKS AND SEWERAGE, October, 1935.

Dribble *Load* *Shoot* *Gush*

One That Needs Blowing; Loading Armored Hose with 2 ft. of Rock Salt; the Quick Shot of Compressed Air (Note Man with One Hand on Cylinder Valve, the Other on Release Angle Valve). Results—Plenty of Water and a Satisfied Customer.

TREATING WATER TO PREVENT CORROSION*

By JOHN R. BAYLIS†

Associate Editor, Waterworks & Sewerage

The writer, in 1930, presented some of the factors involved in preventing corrosion of water pipes.[1] Curves were given to show the solubility equilibrium of iron and zinc compounds in the presence of their respective metals. These curves (Fig. 1) show that practically no iron or zinc will exist in solution when the pH is above 8.0. At a pH of 7.0 several parts per million of either metal may exist in solution in some form in the absence of oxygen, and at a pH of 6.5 quite a large amount of iron or zinc may be found in solution in the absence of oxygen. The article explained how corroding iron took all the free CO_2 and much of the half-bound CO_3 from the water, leaving the water distinctly alkaline where there was no dissolved oxygen present. If the water contained dissolved oxygen the iron was precipitated as a hydrous oxide. Section of a 1-in. cement lined pipe, which had been in service for 50 years at Danvers, Mass., also was shown. The interior of the pipe was in fairly good condition, indicating that the lining was still giving very good protection.

Carrying Capacity of Pipes Greatly Reduced by Incrustation Resulting from Corrosion.—That the carrying capacity of iron pipes may be greatly reduced by tuberculation and incrustation as a result of corrosion is well known to most every one.

Haydock[2] describes how cleaning the tubercles or incrustation from several pipe lines increased the flow. One line carried only about one-half its theoretical capacity, and another about two-thirds. Cleaning a pipe line 3 miles long increased the capacity to the extent that a pumping station could be abandoned, and cleaning another line 5 miles long also enabled the abandonment of a pumping station. The friction loss through a 12-in. line 4 miles long 20 years old was nearly three times that of a new line. The capacity was increased by approximately 35 per cent and the delivered pressure by 20 lb. The gravity delivery of a 16-in. pipe 10.5 miles long was increased 60 per cent by cleaning. Cleaning a 13 mile section of a 12-in. pipe line 22 miles long, which had been in service about 16 years, increased the capacity approximately 35 per cent, and cleaning another section of the line 6 miles in length increased the carrying capacity to 46 per cent.

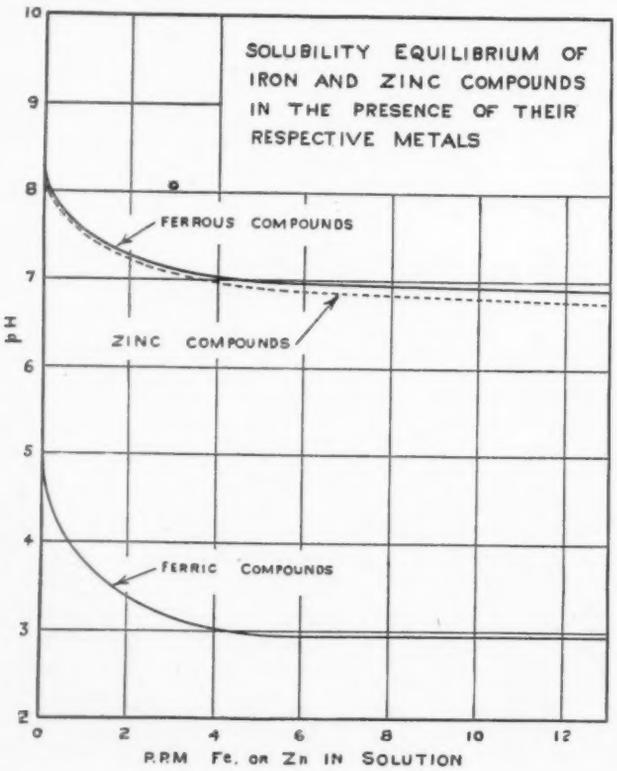

SOLUBILITY EQUILIBRIUM OF IRON AND ZINC COMPOUNDS IN THE PRESENCE OF THEIR RESPECTIVE METALS
FERROUS COMPOUNDS
ZINC COMPOUNDS
FERRIC COMPOUNDS
pH
P.P.M. Fe. or Zn IN SOLUTION

Fig. 1

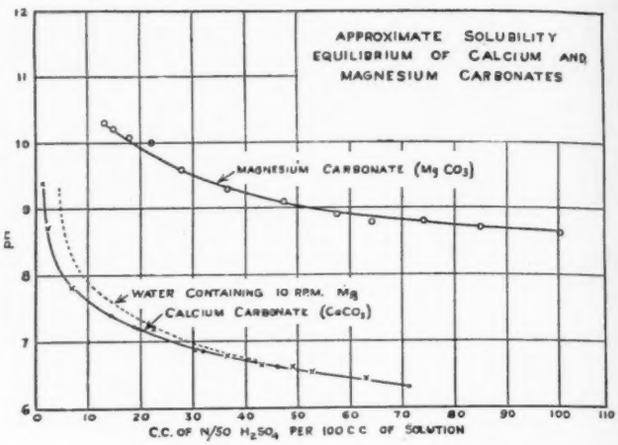

APPROXIMATE SOLUBILITY EQUILIBRIUM OF CALCIUM AND MAGNESIUM CARBONATES
MAGNESIUM CARBONATE ($MgCO_3$)
WATER CONTAINING 10 P.P.M. Mg
CALCIUM CARBONATE ($CaCO_3$)
pH
C.C. OF N/50 H_2SO_4 PER 100 C.C. OF SOLUTION

Fig. 2

Increased Pumping Pressure or Larger Mains Very Expensive.—In some instances it is possible to deliver the desired amount of water through distribution systems that have become partially clogged by increasing the pumping pressure as the friction losses increase, or to install booster pumping stations on the distribution system in certain sections where the pressure is low. Haydock refers to the delivered pressure being increased 20 lb. by cleaning the pipes in one instance. Assume that it was desired to maintain this 20 lb. increased pressure, evidently it was quite expensive to do it at the pumping station. A fair average of the cost of lifting one million gallons of water 1 ft. in height is probably 5 ct. Twenty pounds is equivalent to about 46 ft. in head. In this case it would cost about $2.30 per million gallons to maintain the increased pressure.

If corrosion is going to reduce the carrying capacity of the water mains in a certain city 50 per cent within 20 years, what is the best way of handling such a situation? Should mains be installed large enough to give the desired capacity with a 50 per cent reduction in carrying capacity? The cost of such an investment over what would be necessary if there was no corrosion very likely would be much more than the cost of making the water reasonably non-corrosive.

With the exception of feeder mains, engineers usually design the water distribution system for fire protection. How many engineers allow for a 50 per cent reduction in the carrying capacity of the pipes within 20 years where the water is corrosive? How many make any distinction whatever in the design where the water is corrosive and where it is not corrosive? The writer is of the opinion that corrosion has not been given its proper consideration in the design of water systems. This is largely due to the lack of specific information in the past as to how much the carrying capacity will be reduced within a certain time.

Treatment with an Alkali for Partial Protection.—The literature on the treatment of water to prevent corrosion indicates quite conclusively that the corrosiveness of water may be greatly reduced by proper treatment. It seems that some of the authors of articles on corrosion prevention do not fully realize the importance of a film for protection. So long as iron stains are prevented, some think that this is all the treatment that is necessary. As a matter of fact the carrying capacity of the pipes may be reduced just as rapidly as before, because most of the corroding iron is deposited near where the corrosion is taking place and forms large tubercles that are more effective in reducing the carrying capacity of the pipes than if the rust was

*Excerpts from an article which appeared in WATERWORKS AND SEWERAGE.

†Physical Chemist, Bureau of Engineering, Chicago, Ill.

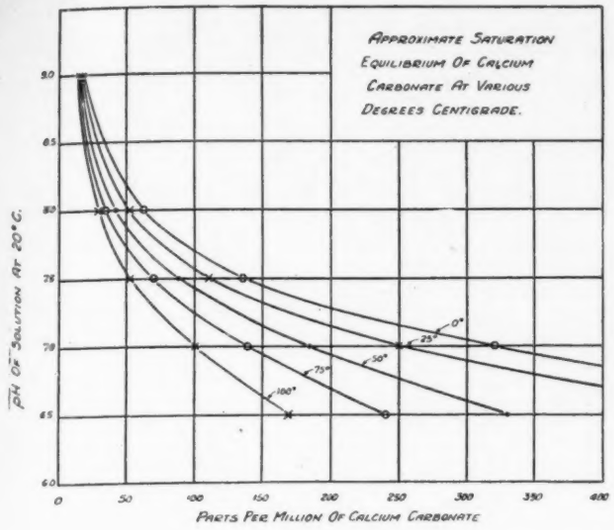


Fig. 3

deposited fairly uniform over the surface of the pipe. Treatment just to the point where red water complaints cease may not materially reduce the cost to the water department for cleaning pipes, constructing new mains, and increasing the pumping pressure.

Water Just Saturated with Calcium Carbonate s the Most Desirable Equilibrium.—As a general rule, it might be said that water saturated with calcium carbonate is the most desirable equilibrium when everything is taken into consideration. This is not strictly true for very soft waters, for it is desirable to have the water slightly supersaturated part of the time so as to form a thin protective film. Where the calcium carbonate alkalinity of the water is below 30 parts per million the application of lime to produce a slight supersaturation of calcium carbonate should be done with considerable care, otherwise caustic water might be produced. After a thin coating has been formed on the pipes the water should be kept saturated with calcium carbonate practically all the time to keep the coating from being dissolved. It is admitted that the very soft waters are the most difficult to protect, for we are working with equilibriums difficult to maintain exactly on the saturation point. It may be almost impossible to do this with the force available in small plants and it may be necessary to sacrifice some protection to avoid occasional caustic taste in the water. There is no reason why large plants with skilled supervision should not be able to maintain a fairly constant equilibrium.

Table I—Rapid Increase in pH Caused by Corroding Iron

Alkalinity	Time in Contact with the Iron Minutes	pH	Fe in Solution
39	0	7.2	
	1	7.3	
	2	7.4	
	3	7.7	
	5	8.2	
	10	9.2	
	15	9.4	
35	20	9.6	0.0tr

Where water has a calcium carbonate alkalinity in excess of about 30 it is easier to protect the pipes. If this water is placed in contact with an iron surface the iron going into solution will take up all the free Co_3 that is in the water and part of the half-bound CO_2. Table I shows how quickly the pH changes in water exposed to iron lathe turnings. After the pH reaches 8.1 no free CO_2 is present. This was due to the CO_3 combining with the corroding iron.

At any point on the surface of an iron pipe where corrosion starts to take place due to the surface becoming exposed in some manner, there is a tendency for the iron going into solution to take up the free and part of the half-bound CO_2, producing a supersaturation of calcium carbonate in the immediate point where corrosion is taking place. This supersaturation helps to quickly form a coating over the exposed surface both by precipitating the iron compounds and also some calcium carbonate, especially when the water has a fairly high alkalinity. If the water in the mains is saturated with calcium carbonate, then the precipitated calcium carbonate will not be dissolved out of the percipitate. It will remain where it is precipitated to offer protection against further corrosion.

Most natural waters contain magnesium carbonate as well as calcium, and the presence of a considerable amount of magnesium may materially alter the equilibrium curve. This is shown by the curves in Fig. 2. The presence of sodium carbonate also alters the curve. When sodium carbonate is present the only way the saturation equilibrium of the water in regards to calcium carbonate can be determined is by actual trial.

Temperature also has an effect upon the saturation equilibrium of calcium carbonate. The curves shown in Fig. 2 were determined at room temperature, that is, about 20 to 22° C. The other curves are based on actual tests, but not enough were run to state that the curves are absolutely correct. They should be regarded as somewhere near the true lines.

Corrosion prevention by treatment of the water has been demonstrated to be practical and economical. This being true, then it seems that all corrosive waters should be treated.

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[1]Baylis, J. R. How to Avoid Loss by Pipe Corrosion. Water Works Engineering, 83:13-14, 31-32, 35-36, Jan. 1, 1930.

[2]Haydock, C. The Cleaning of Cast Iron Water Pipe Lines Jour. Am. Water Works Assoc., 11:533-4, May, 1924.

The Influence of Dissolved Oxygen on Corrosion Losses

Engineers and chemists are constantly studying the theories and mechanics of corrosion because it is only through better understanding of fundamentals that they will be able to diminish losses due to corrosion.

Thirty years ago, R. W. Whitney, now vice-president of the general Electric Company, announced that the corrosion of metals was an electrochemical process and this view is now generally accepted. When a metal is in contact with even slightly acidic solutions, corrosion takes place by the chemical process of the metal replacing the hydrogen in the acid. The acid dissolves the metal and thereby hydrogen is released. The same holds for corrosive waters.

Released hydrogen coats the metal surface with an electrically charged layer that prevents the chemical reaction from continuing at the initial rate. • If the hydrogen layer is built up to a sufficient thickness the reaction is practically stopped. However, under natural conditions, the hydrogen combines with the oxygen of the air or that dissolved in the water to form water and solution of the metal goes on. The *amount of oxygen* available to remove the protective hydrogen blanket determines the extent of corrosion.

Impure metals are corroded more quickly as a rule than pure metals. Electrochemists believe that this is due to the impurities taking up the oxygen. Contrary to the popular belief, however, pure metals are subject to corrosion under the action of certain acid solutions. Prof. O. P. Watts of the University of Wisconsin has recently shown that if oxygen is absolutely excluded copper will not corrode in a solution of sulfuric acid, a reaction that is very rapid in the open.

The importance of the dissolved oxygen content of corrosive water is thereby once more emphasized. When this element is present in high concentration a higher pH value must be maintained to prevent corrosion of mains than otherwise; and, particularly of household services or piping subjected to increased temperatures which create accelerated attack.

This suggests that there is some question as to the merits of aeration of waters which are normally aggressive, unless the pH value is raised sufficiently by alkali addition to reduce the hydrogen ion concentration considerably; below that which is commonly considered to represent a neutral water. It has in fact been demonstrated that ofttimes waters high in oxygen content and low in hardness must be raised to pH 9.5 in order to check even the cold water corrosion of mains. In some aerated waters a pH value of 10 to 10.5 is required, which is costly and questionable practice with public supplies.

DETERMINING THE NECESSARY TREATMENT TO PREVENT CORROSION*

By P. L. McLAUGHLIN

Sanitary Engineer, West Virginia Water Service Co., Charleston, W. Va.

Difficulties from red water and corrosion have necessitated corrective treatment at nine of the fifteen water works plants owned by the West Virginia Water Service Company in the State of West Virginia.

All nine of the supplies considered are purified in rapid sand filtration plants. Lime is applied to the filtered water in the clear water wells at seven of the plants.

Satisfactory experiences can be cited for the plants using corrective treatment. Without exception, the managers of these properties report that present conditions are far superior to those experienced prior to the use of the treatment. Practically no complaints of red-water are received by them today except occasionally from consumers residing on dead ends of the distribution systems. Furthermore, all managers report the presence of a white film, or protective coating, in the pipes of their distribution systems, although the extent to which this coating has been deposited varies with the different waters and seems to be dependent upon the size of the distribution system, the length of time the treatment has been in use and the accuracy with which it has been carried out.

The Method Adopted

The treatment consists of producing a plant effluent which is in "chemical balance"; that is, at the saturation point with respect to its power to dissolve calcium carbonate. This procedure is based on accepted principles that a water which no longer dissolves calcium carbonate should tend to form a protective coating in the mains and thus prevent corrosion. The writer uses the following procedure for rapidly determining, on a single sample of water, the correct pH to maintain through lime addition.

The procedure adopted assumes that the degree of undersaturation or the degree of supersaturation (within the limits required for performance of the test), of a water at a given alkalinity and pH is a function of the degree of increase or the degree of decrease in the total alkalinity of that water after contact with an excess of pure $CaCO_3$. Therefore, to determine the pH value at which the saturation point of an undersaturated water is attained, it is only necessary to increase the pH of a sample of that water (with lime) through a series of arbitrary pH values. Then, determine the degree of undersaturation, or supersaturation, as expressed by parts per million gain or loss in total alkalinity after treatment with $CaCO_3$, of the samples treated to produce increasing pH values. The use of a graph is then resorted to. The following example of the method as actually applied will illustrate the procedure.

*From WATER WORKS AND SEWERAGE—March, 1936.

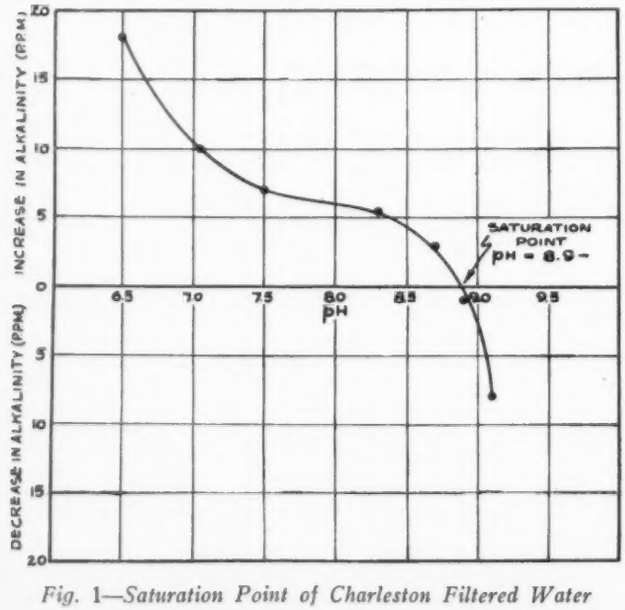


Fig. 1—Saturation Point of Charleston Filtered Water

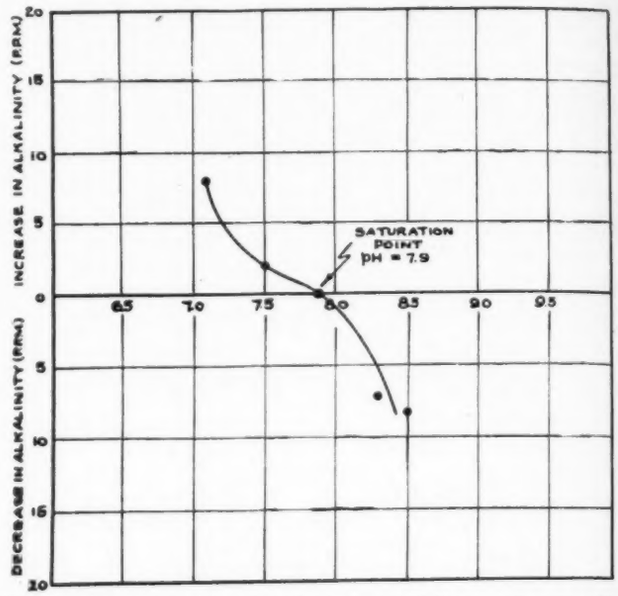


Fig. 2—Saturation Point of Nitro Filtered Water (Oct. 23, '35)

Test Procedure

A one gallon sample of filter effluent, taken ahead of plant treatment with lime, was collected in a gallon glass bottle. The pH of the sample was determined and found to be 6.5 and the total alkalinity (Methyl Orange) 18 p.p.m. About 200 c.c. of the sample was then transferred from the bottle to an Erlenmeyer flask. One teaspoon full of C.P. powdered (precipitated) $CaCO_3$ was added to the water in the flask and stirred for five minutes. The carbonate was then allowed to settle, after which the supernatant liquid was filtered through filter paper and the alkalinity determined on the filtered portion. This alkalinity was 36 p.p.m., an increase of 18 p.p.m. over that of the original sample in the gallon bottle. The increase in alkalinity was then plotted against the original pH value (6.5), thus determining the first point on the curve. (See Fig. 1.)

Hydrated lime in solution (lime-water) was then added gradually to the original sample in the gallon bottle and thoroughly mixed by stirring until the pH of the sample had increased to approximately 7.0—in this instance, 7.05. At this pH the alkalinity was determined on an unfiltered portion and found to be 24 p.p.m. A 200 c.c. portion of the sample was transferred, as before, to an Erlenmeyer flask; $CaCO_3$ was added, mixed for 5 minutes, settled, filtered and the alkalinity of the filtrate determined. It had increased to 34 p.p.m., representing a 10 p.p.m. pick-up of alkalinity from the carbonate as compared to an 18 p.p.m. pick-up in the first test on the unlimed sample. The second point on the curve was thus located, the increase in alkalinity of 10 p.p.m. being plotted against the pH of 7.05, which was that of the lime treated test sample.

More lime was then added to the water in the gallon bottle until the pH was raised to 7.5. At this pH value the alkalinity was 25 p.p.m. As before, a portion of the sample was removed and treated with $CaCO_3$, and an increase in alkalinity of 7 p.p.m. was observed. This increase was plotted against pH 7.5, forming the third point on the curve.

In a similar manner the pH of the sample in the bottle was raised with lime to pH values of 8.3, 8.7, 8.9 and 9.1 and the differences in alkalinities after treatment with $CaCO_3$ were plotted against each of these pH values.

It will be noted from the curve that at pH 8.7 the water was only slightly undersaturated, the increase in alkalinity after treatment with $CaCO_3$ being but 3 p.p.m. At a pH of 8.9, however, the alkalinity *decreased* 1 p.p.m. after treatment with $CaCO_3$, showing that at this pH the water was slightly supersaturated and some calcium alkalinity had deposited out on the suspended carbonate. Therefore, the exact point of equilibrium lay between these two pH values, or for all practical purposes at pH 8.9—see Fig. 1. The pH of the sample in the bottle was then increased to 9.1 in order to portray the trend of the curve more accurately.

Having determined the saturation point of the sample by the above procedure, its adaptation to plant control consists merely in adding enough lime to the filtered water to maintain a pH value of 8.9 or thereabouts in the plant effluent.

Inasmuch as free carbon dioxide gas (CO_2) influences the solubility of calcium carbonate in water, care should be taken in carrying out the procedure not to allow the sample to come in contact with the air any more than possible, and to avoid shaking or violent agitation of the sample. Removal of portions of water from the original sample should be made with a transfer pipette and a good grade of filter paper should be used for filtering the portions treated with $CaCO_3$. The procedure is carried out at room temperature and it is believed that a negligible error may be introduced thereby, since in the case illustrated the temperature in the Charleston laboratory was some 10 to 15 degrees higher than the temperature of the water in the clear well and in the mains.

A convenient and explanatory method of recording the data obtained in carrying out the procedure is shown below:

Filter Effluent—Charleston, October 17, 1935

pH 6.5	$CaCO_3$ added, mixed		Undersaturated
Alk. 18	settled and filtered	Alk. 36	+18
Lime added:			
pH 7.05	$CaCO_3$ added,		Undersaturated
Alk. 24	etc.	Alk. 34	+10
Lime added:			
pH 7.5	$CaCO_3$ added,		Undersaturated
Alk. 25	etc.	Alk. 32	+7
Lime added:			
pH 8.3	$CaCO_3$ added,		Undersaturated
Alk. 27	etc.	Alk. 33	+6
Lime added:			
pH 8.7	$CaCO_3$ added,		Undersaturated
Alk. 28	etc.	Alk. 31	+3
Lime added:			
pH 8.9	$CaCO_3$ added,		Supersaturated
Alk. 32	etc.	Alk. 31	—1
Lime added:			
pH 9.1	$CaCO_3$ added,		Supersaturated
Alk. 35	etc.	Alk. 27	—8

The Influence of Calcium Bicarbonate In the Water to Be Treated

It is known that when the calcium carbonate content of a water is less than 25 to 35 p.p.m., the calcium carbonate content must be built up to this amount before corrosion can be effectively prevented. The alkalinity of the water used to illustrate the procedure was but 18 p.p.m., and the water was therefore below the prescribed limits as to its calcium carbonate content. However, this deficiency was automatically taken care of in the procedure and in its adaptation to plant control methods by the use of lime which increased the calcium carbonate content to the point required for saturation. Several of the water supplies requiring corrective treatment operated by the West Virginia Water Service Co. normally, or occasionally, have calcium carbonate contents in excess of the minimum requirements. The procedure for determining the pH of the saturation point for these waters is carried out with lime in the same manner as described.

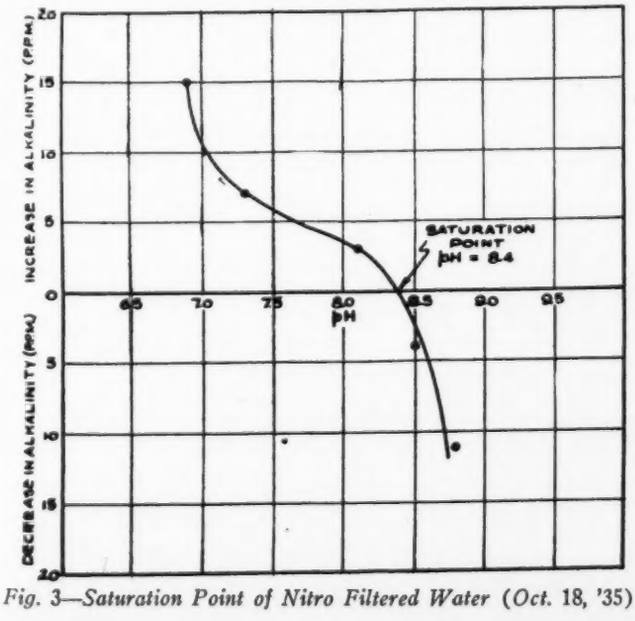


Fig. 3—Saturation Point of Nitro Filtered Water (Oct. 18, '35)

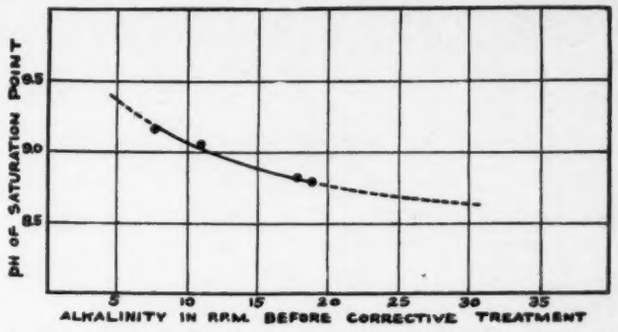


Fig. 4—pH Saturation Point vs. Total Alkalinity—Operating Curve

Figure 2 shows the curve obtained by the procedure on such a water. The sample was taken recently from the filter effluent of the Nitro plant which treats Kanawha River water and had a pH of 7.1 and an alkalinity of 47 p.p.m.

The saturation point of the same supply, determined five days previously, is shown by Fig. 3. In this case, the pH of the filter effluent before lime addition was 6.9 and the alkalinity was only 39 p.p.m.

Inasmuch as the pH of the saturation equilibrium with calcium carbonate of any water depends, among other factors, upon the concentration of dissolved alkaline compounds in that water, it has been found, as would be expected, that the pH of the saturation point varies with changes in the chemical composition of the water. As the alkalinity decreases, the pH and total alkalinity at the saturation point increases and vice versa.

Protective carbonate coatings will be quickly dissolved and removed if the water in contact with them is undersaturated. Also, such coatings will be built up too rapidly if the pH of the water is carried too high above the saturation point. Therefore, to practice effective control in the treatment for the prevention of red-water and corrosion on a supply of fluctuating chemical character it is necessary to vary the pH of the plant effluent as frequently as is required to meet changing raw water conditions.

A General Curve for Plant Control

For a given supply, saturation points (pH values) can be determined by the procedure for various alkalinity values and a saturation curve plotted from this data. Figure 4 represents such a curve under process of development for the Charleston water. With experience the number of trial tests can be reduced, and once the curve has been established for a supply, the approximate pH of the plant effluent of that supply required to bring the water to equilibrium with calcium carbonate can be selected at once by merely determining the total alkalinity of the water to be treated. Then, if desired, a single check test should confirm this value if made on the plant treated water.

When corrective treatment is first applied to a water supply it is probably best to deliver the water to the distribution system in a slightly supersaturated condition for a period of several months or until a thin protective film has been built up in the mains. The treatment should then be reduced and maintained as closely as possible at the pH of the saturation point with calcium carbonate. It will be found difficult, if not impossible, to maintain the pH at exactly the desired value under ordinary methods of plant control but the slight variations experienced should not impair the success of the treatment in so far as overall practical results are concerned.

In closing, it should be pointed out that the procedure presented in this paper is not held to be without errors but it is believed that the procedure provides a rapid and workable method, sufficiently accurate for the purposes required, whereby the pH of the saturation point of a water can be obtained from a single sample of that water, thereby eliminating cut and try methods on a plant scale. At least it has been successfully applied to the low alkalinity waters encountered in several West Virginia plants.

CHECKING TUBERCULATION BY CHLORAMINE TREATMENT*

By J. WALTER ACKERMAN

General Superintendent, Consolidated Water Co., Utica, N. Y.

The results from the ammonia-chlorine treatment in suppressing tuberculation of the 12-mile cast-iron supply main at Utica, N. Y., constitute a new chapter in corrosion control and depreciating capacity values of water mains.

When Mr. Ackerman first reported his observations informally before the American Water Works Association in 1934, he considered the findings both interesting and indicative, rather than conclusive. Amongst his audience were many skeptics. A year later sufficient supporting data had been accumulated by him to warrant a further informal report before the same association. Now, still a year later, the results are more than ever convincing. It was with this in mind that WATER WORKS AND SEWERAGE asked Mr. Ackerman to present to its reader his data-graphs and the accompanying report of the continuing effectiveness of the treatment which maintains sterile conditions throughout the 12-mile main.—Editor.

The Consolidated Water Co. of Utica, N. Y., constructed in 1906 a single 24-inch cast iron water main for transmission purposes to bring water from the West Canada Creek at Hinckley, N. Y., to Marcy Summit, a distance of 12.1 miles, for the purpose of supplying the city of Utica with water from this source in addition to that already supplied from the southern group of reservoirs. This supplied sufficient water for use in the city until 1922, when the use had increased and delivery of this line had diminished to a point where it was only delivering about 8.5 M.G.D.

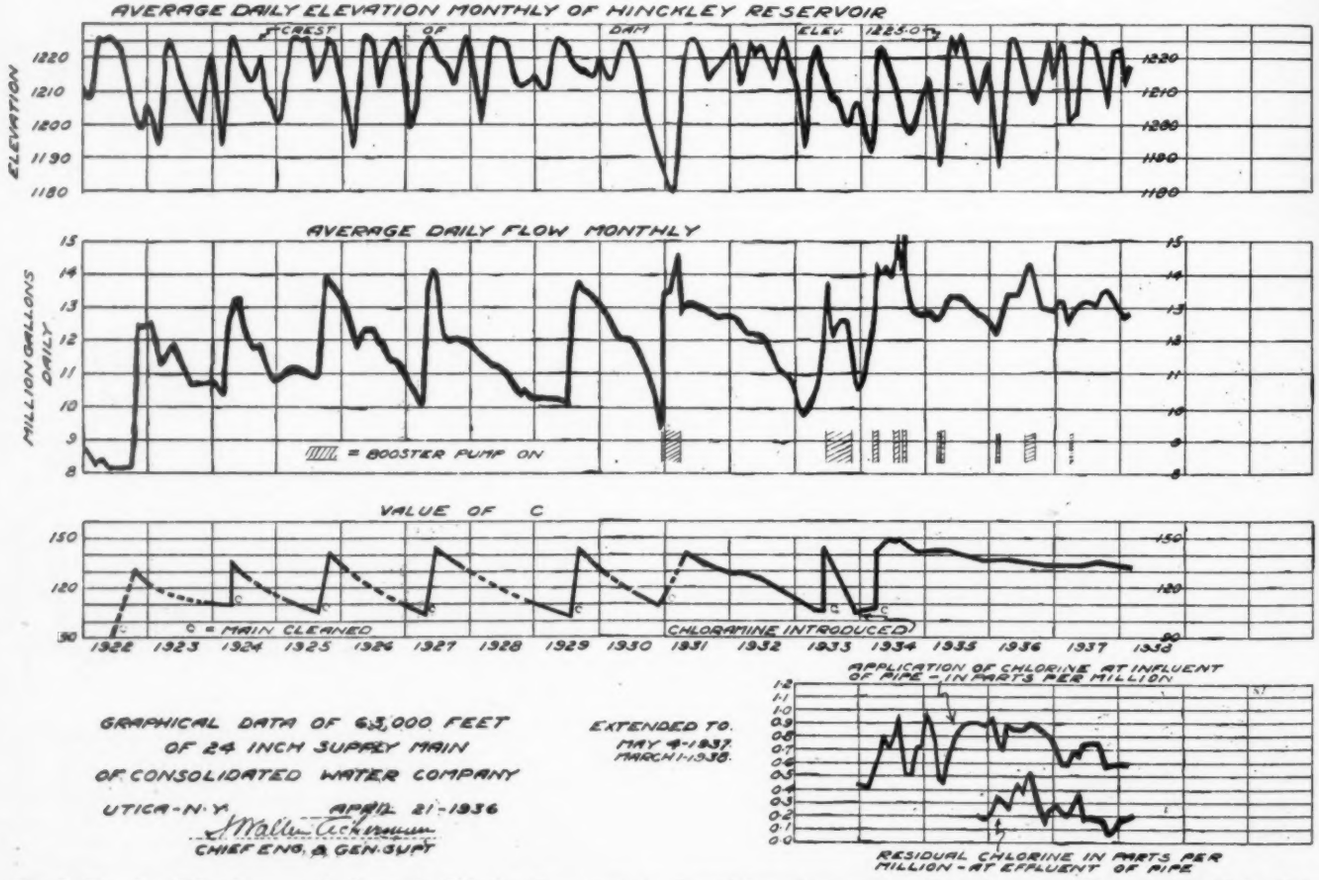
Records in the office indicate that in 1917 this line was examined by Metcalf & Eddy, Engineers, and the value of "C" in the Hazen-Williams formula was found to be 109. On July 5, 1921, "C" had dropped to 95, and in November of the same year it had dropped further to 93.5. It later became necessary to clean this line and the National Water Main Cleaning Company was engaged for this purpose and cleaned it on October 5, 1922.

Table A shows the number of times the main has been cleaned since that date and the various "C" values before and after cleaning.

TABLE A

Date Cleaned	Months Since Previous Cleaning	Reservoir Elevation	—Delivery— Before	After	"C" Before	"C" After
		1199.9	Oct. '22	Oct. '22	June '22	Oct. 8, '22
Oct. 5, 1922		1199.9	8.5	12.3	90	131
		1192.3	Mar. '24	May '22		
Apr. 1, 1924	18	1226.1	10.3	13.2	109	136
		1211.8	Aug. '25	Oct. '25		
Aug. 27, 1925	17	1220.4	10.5	13.9	106	142
		1222.7	Apr. '27	June '27		
May 4, 1927	20	1223.1	10.1	14.2	103	144
		1223.7	July '29	Sept. '29		
Aug. 6, 1929	27	1215.6	10.0	13.8	102	142
		1193.3	Nov. '30	Mar. '31	Nov. '30	Sept. '31
Jan. 3, 1931	17	1249.7	10.2	14.6	109	133
		1223.6	May '33	July '33	Apr. '33	July '33
June 16, 1933	29	1273.8	10.3	14.0	106	136
		1276.4	Apr. 2, '34	Apr. 12, '34		
Apr. 8, 1934	10	1226.1	11.9	13.7	111	144

*From WATER WORKS AND SEWERAGE, May, 1936.


AVERAGE DAILY ELEVATION MONTHLY OF HINCKLEY RESERVOIR
CREST OF DAM ELEV. 1225.0
ELEVATION
1220
1210
1200
1190
1180
AVERAGE DAILY FLOW MONTHLY
MILLION GALLONS DAILY
= BOOSTER PUMP ON
VALUE OF C
C = MAIN CLEANED
CHLORAMINE INTRODUCED
1922 1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937 1938
APPLICATION OF CHLORINE AT INFLUENT OF PIPE - IN PARTS PER MILLION
RESIDUAL CHLORINE IN PARTS PER MILLION - AT EFFLUENT OF PIPE
GRAPHICAL DATA OF 63,000 FEET OF 24 INCH SUPPLY MAIN OF CONSOLIDATED WATER COMPANY
UTICA-N.Y. APRIL 21-1936
CHIEF ENG. & GEN. SUPT.
EXTENDED TO MAY 4-1937 MARCH 1-1938.

Graph Showing Effectiveness of Ammonia-Chlorine Treatment in Sustaining the carrying Capacity of a Cleaned CI. Main 12.1 Miles in Length. Compare the Friction Coefficient Curve for 1930 and 1934 with That for 1934-1938.

Until December, 1933, this 24-inch line had carried nothing but untreated water, chlorination being carried out at the local distributing reservoirs. In December, 1933, chlorine-ammonia treatment of the water was started at Hinckley, and the "C" value at the time the treatment began was 105. In April, 1934, just prior to the last cleaning, a measurement of "C" showed a value of 111, an apparent improvement of about 6 p.c. in carrying capacity after the four months of treatment by chloramines, without cleaning.

The last cleaning of this line was done as noted on April 8, 1934, and the "C" value was raised from 111 to 144. No mechanical cleaning has been done since that date, but the line has been continuously treated with chloramines to the present time.

The graph accompanying this article shows the variations in the level of the water in the Hinckley Reservoir, which varies the head on this pipe line and consequently varies the flow due to this change in head. It shows the monthly average flow in each month from 1922 to date, also the chlorine application and the resultant "C" value before and since the application of the ammonia-chlorine treatment. The results seemingly speak for themselves.

Method of Checking "C" Value

Just a word as to the method of checking this "C" value. Careful and rechecked determinations of reference level points at each end of the 12.1 miles of pipe have been made. Consequently, physical observations of the water level in the standpipe at one end of the line and the water level at Hinckley Dam at the other end give the actual slope. The amount of flow is determined by a venturi meter, but at no time has the value of the amount of flow been accepted except after being checked by manometer or pitot tube, and, in fact, a number of these determinations are made either by the manometer on the venturi tube or the pitot tube near this same place. Therefore there are some slight variations in the determining of the "C" value of the period from April, 1934, to the present time. While there appears to be somewhat of a downward trend, it is so small as to be almost negligible, as, of course, the different methods of computing the flow vary about 2 to 3 per cent, according to the method used for this determination, which is as close as can be expected for equipment of this nature.

The Marcy standpipe, which is at the lower end of the 12.1 miles of 24-inch pipe in question, is 2.3 miles from Marcy Reservoir, where the actual chlorine residual is taken, as the Marcy standpipe is in a more or less inaccessible location a part of the year. The residual obtained and shown on the chart is less, therefore, than the actual residual at the end of the 12.1 miles of 24-inch pipe, as the chlorine demand in the 2.3 miles to Marcy Reservoir is considerable in this uncleaned and badly tuberculated section of pipe, which we believe is gradually being cleaned by the action of the chloramines.

Addenda—1937-1938

The above article was prepared in April, 1936. From Mr. Ackerman comes the following advice and a new graph, which carries forward the flow and friction data into 1938, although the graph carries the original date—April 21, 1936. The author explains that the data are checked by frequent readings taken from a checking manometer on the venturi tube, and the use of a Cole rod and Lanham rod. These check readings have shown a difference of but 1 to 3 points in obtaining "C" values of 134 to 142 in the Utica situation.

Mr. Ackerman states: "It will be noted that there seems to be a slight diminution of the "C" value during the past year, but hardly enough to make very much difference in our flow. As a matter of fact we are actually getting more water down now than heretofore, which, I think, is due to the fact that all of these figures constitute the result between the Hinckley Dam and our Marcy standpipe only."

"Below the Marcy standpipe to our reservoirs are two lines of pipe, one 24-inch and one a 16-inch. We know that the 16-inch is very badly tuberculated. About three years ago a test was made on it and the 'C' value was down to about 60. But, since we had at least a theoretical capacity greater than the line above, we did not clean these two lines. We do find now that the water does not stand as high in our standpipe with the same dam elevation at Hinckley as heretofore, which rather indicates that the chloramines have been gradually cleaning the 16 and 24 inch lines below the Marcy standpipe."

"These are just some added points to give you a better understanding of the problem."

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USE INERTOL

1. ON ALL CONCRETE IN CONTACT WITH WATER BUT NOT VISIBLE: for "tile-surfacing" the walls of filter beds below the sand line, for waterproofing covered reservoirs and basins, for eliminating slime and accelerating the flow in tunnels, conduits, flumes. Apply INERTOL No. 49 in 2 coats, at the rate of 1 gallon for 150 square feet, each coat.

2. ON ALL CONCRETE IN CONTACT WITH WATER AND EXPOSED TO VIEW: for "tile-surfacing" the walls of filter beds above the sand line, for waterproofing coagulating basins and clarifiers, for eliminating slime and retarding algae in flumes, channels and open conduits. Apply RAMUC ENAMELS as per color chart, in 2 coats, at the rate of 1 gallon for 200 square feet, each coat.

3. ON ALL CONCRETE BRICK OR PLASTER ABOVE WATER: for protection against condensation of water and chemicals and for decorating floors, walls and ceilings of pump stations and filtration plants with a clean, non-peeling and washable finish. Apply RAMUC ENAMELS as per color chart, in 2 coats, at the rate of 1 gallon for 200 square feet, each coat.

4. ON ALL IRON, STEEL OR WOOD SUBMERGED UNDER WATER: for durable protection against corrosion of wash water troughs, stand-pipes and tanks (inside), chemical feeding troughs, etc. Apply INERTOL No. 49 (black) in 3 coats, at the rate of 1 gallon for 300 square feet, each coat.

5. ON ALL IRON, STEEL AND WOOD ABOVE WATER: for protection against condensation of water and chemicals as well as general atmospheric conditions on structural steel in filter plants, pipe galleries, on motor housings, pumps and valves, hydrants, etc. Apply GLAZOFLEX ENAMELS as per color chart, in 2 coats, at the rate of 1 gallon for 300 square feet, each coat. On rough, very absorbent or brand new surfaces, use first a priming coat of GLAZOFLEX PRIMER, applied at the same rate.

6. On CONCRETE BRICK AND STUCCO EXPOSED TO DRIVING RAINS AND SEVERE WEATHERING CONDITIONS: for waterproofing and frostproofing of outside building walls, aerator walls, spray ponds, etc. Apply PLUVOL (transparent) in 3 coats, at the rate of 1 gallon for 400 square feet, each coat.

York, Pa., Filtration Plant Waterproofed with INERTOL Throughout. Engrs.: Fuller & McClintock, New York City.

LIMESTONE CONTACT BEDS FOR CORROSION CONTROL*

Have Features Attractive for Small Installations

By I. M. GLACE, C.E.

Consultant and Supervising Engineer, Harrisburg, Pa.

The water served Dillsburg, Pennsylvania, is typical of that of many other similar supplies serving the considerable number of communities located in or contiguous to the Appalachian Mountains in Pennsylvania.

The following analysis of the Dillsburg water is characteristic of water of the territory—very soft and palatable, but corrosive and tuberculating:

Hardness	12 p.p.m.
Alkalinity	8 p.p.m.
Carbon dioxide	20 p.p.m.
pH	5.4

From a bacteriological standpoint the water is of high quality.

Complaints

Tuberculation of the mains had resulted in a noticeable decrease in carrying capacity and pressure losses at fire hydrants. In order to cooperate with the local fire department the water company, which is exceptionally progressive for a community of this size, retained a nationally known water main cleaning company to scrape the lines. From the standpoint of recovery in main carrying capacity this operation was a success. Naturally, the cleaning exposed some fresh metal, and complaints of "red water," laundry stains, and iron tastes were received by the company. It was then that the writer and the Wayne Laboratories, with whom he is associated, were retained to recommend relief measures.

Consideration was given first to standard methods for the control of corrosion through the application of hydrated lime, other alkaline salts, to boost pH values. Such a procedure, however, requires more or less constant attention and close chemical control to be really effective. Moreover, the cost of the operations, for a small company, is excessive and remoteness of the proper point of application at Dillsburg would make it more so. A search was made, therefore, for some easier solution of the problem, one which might be less exacting in control.

Limestone—Nature's Corrective

The suggestion was made by Wayne Laboratories that beds of limestone be prepared and the spring water passed through for treatment. In the absence of concrete information and technical data on such treatment no attempt was made to put such a plan in operation because lime treatment seemed the more positive and certain method.

At about this time an article appeared in WATER WORKS & SEWERAGE, under the name of Henry Ryon, describing the experimental work and full plant scale results at a state institution on Long Island, where crushed marble contact filters had been installed for the correction of a well water which has practically the same characteristics as that of the spring water at Dillsburg.

Using the Ryon data, from WATER WORKS AND SEWERAGE as a guide, an experimental unit (here sketched) was installed at Dillsburg. It was continuously operated for almost a year before determining on the plant scale design and practicability of the scheme, under winter conditions, life of the marble or limestone, and other important practical considerations, such as cloggage, difficulties and the like.

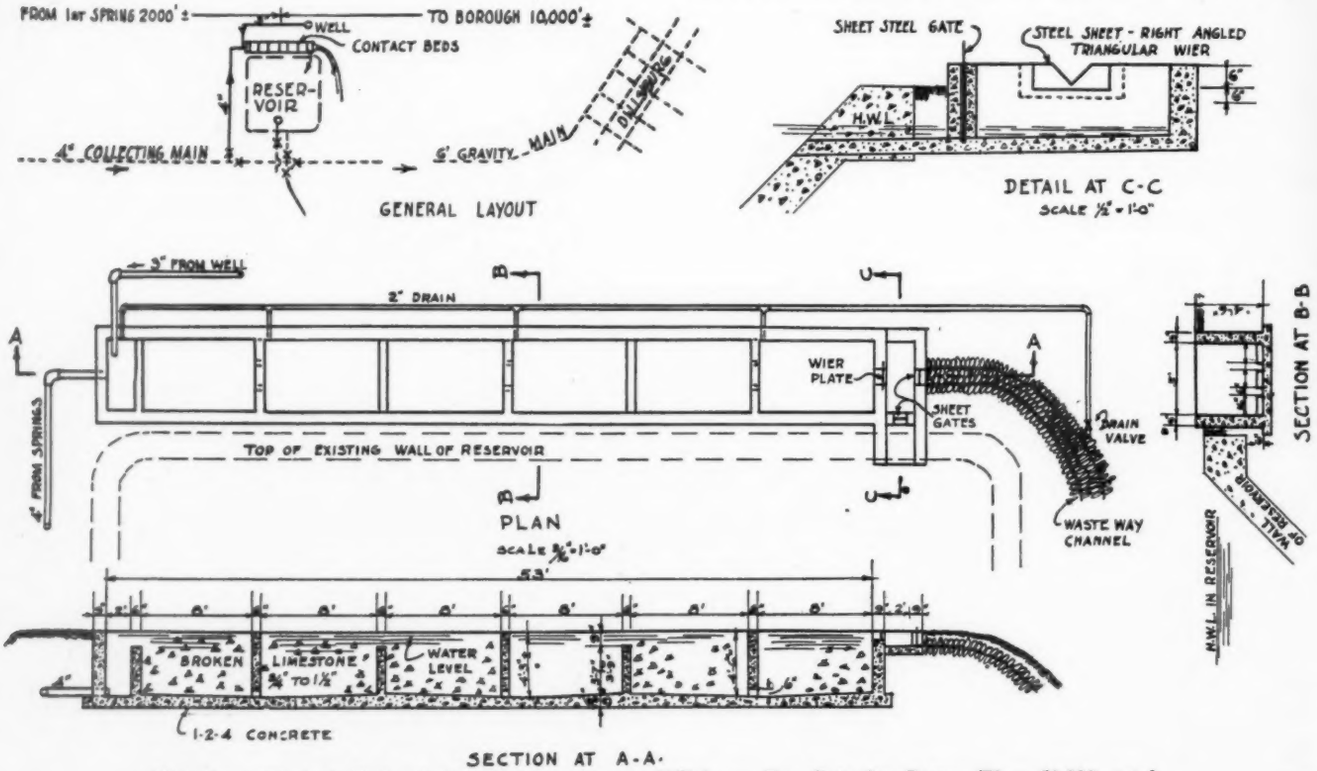
The incoming raw water and the outgoing treated water were metered as shown, using standard ⅝-inch service meters; the feed and discharge lines were of new galvanized iron pipe. The 50 gallon wooden barrel, and the terra-cotta pipes which serve as baffles for proper distribution through the tank, are filled with broken (high-calcium) limestone of about 1 inch size. The flow of water was regulated during most of the period at a rate of about 220 gals. per day, or slightly less than a pint per minute. It is interesting to note that this small amount of water was measured quite accurately (within a five per cent error) by the meters, as checked by volumetric determinations. The influent meter was operating under a head of only about one foot.

At this low rate of flow it is estimated that the water in its passage through the tank had a 2 hour contact, based on approximately 50 per cent voids in the limestone bed.

Observations and Deductions

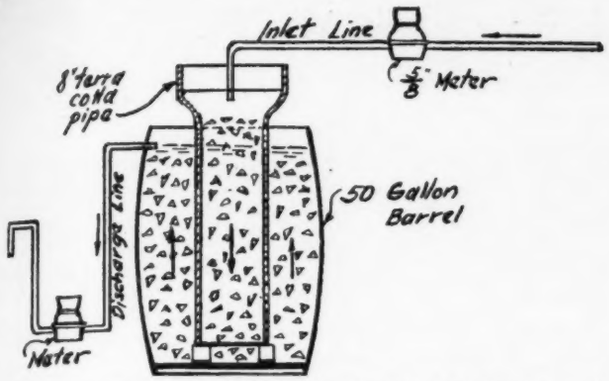
At the end of the first six months' run, the inlet and outlet pipes and the meters were dismantled and examinad. The inlet pipe was already tuberculated and badly stained. The inlet meter likewise was heavily stained, but not tuberculated. The outlet pipe, on the other hand, showed no iron discoloration, and no tu-

*Taken from an article in WATER WORKS AND SEWERAGE.



Limestone Contact Beds Under Construction at Dillsburg, Pa. Capacity Better Than 50,000 g.p.d.

*In the magazine section of this issue appears an article by Mr. Glace which reports on the results secured from the plant scale installation made at Dillsburg, Pa.—Ed.



Experimental Calcium Carbonate Contact Bed Set Up and Operated in Corrosion Control Studies at Dillsburg, Pa.

berculation or pitting, but was covered with a soft and very light gray film. The outlet meter was not affected one way or the other.

The limestone at the top of the down-flow (inlet) compartment, was also excessively stained but, the stone surfaces at the outlet side were as clean apparently as on the day they were placed.

During this six-months period the rate of flow was uniform, it being controlled by means of a drilled coin union placed in the inlet line. Later a larger orifice was inserted and the rate tripled, with an immediate decrease in the efficiency of the treatment being noted.

Based on a number of determinations made in the field and in the laboratory (with results averaged), the experimental unit produced a very consistent effluent as follows:

	Raw	Treated
Hardness	12 p.p.m.	28
Alkalinity	8 p.p.m.	24
Carbon dioxide	20	2
pH	5.4	7.4

The practical benefits of a non-corrosive water have recently been well demonstrated by the New England Water Works Association, in its report on Pipe Line Friction Coefficients, which emphasizes the inter-relationship between calcium carbonate, alkalinity, and CO_2 content, and the value of pH of the supply as an index of rate of capacity loss. The figures given above seem to be in agreement with the findings of the committee.

As a result of this experimental work, a full-scale plant (see sketch) has been designed, using the same principles of treatment, and is now being installed at Dillsburg.

Additional Observations

Further evidence of the efficacy of this type of treatment, for control of corrosion, has been secured in another and muchl arger community. The supply is essentially the same as that at Dillsburg.

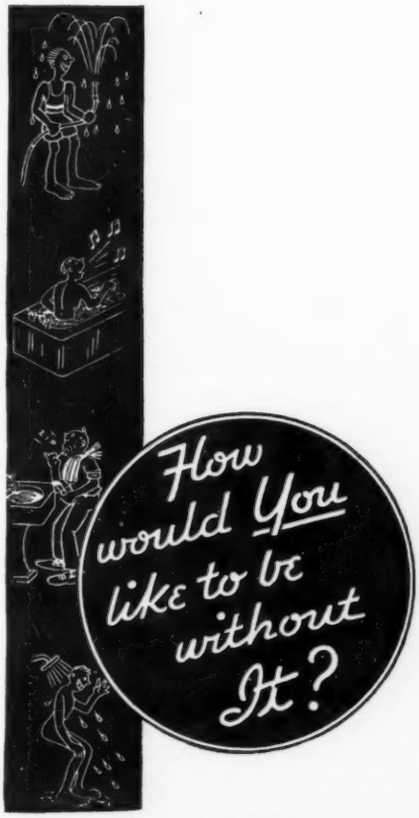
At the present time complaints of "red water" are frequent occurrences. This condition existed in the home of the local superintendent, who, on his own initiative, removed the iron service lines in his home and installed copper service pipes throughout, as well as a copper hot water tank.

In less than a month after the copper pipes were installed, the iron stains formerly present on the plumbing fixtures disappeared, and the typical green stains of copper became noticeable. To these the writer's attention was directed at about the time that the first definite data had been secured at Dillsburg.

As a further experiment, therefore, a 50 gallon galvanized iron hot water tank was secured, filled with ½-inch broken limestone, and installed on the service line into the superintendent's home. An immedate improvement followed. The copper stains disappeared from the fixtures and, after six months' operation, have not again re-appeared. Because of the great irregularity of flow of water in this as in other private homes, the pH and other characteristics of the treated water have not been so uniform as were those of the Dillsburg unit, which was operated at a constant rate of flow. However, at no time did the pH of the limestone-passivated tap water fall below 7.0 and has been usually higher.

It is recognized that additional tests and further demonstrations are necessary before final conclusions are justified on this simplified type of treatment. The results to date, however, have definitely surpassed expectations and the method is attractive even if some supplementary chemical treatment proves advisable at a later date.

Lest They Forget!
(A Message to Consumers)



"Pure water is the best of gifts that man to man can bring." —Lord Neaves.

The other day when I asked my little girl what water is she said, "It's what comes out when I open the faucet." This set me to thinking about how much all of us take for granted our water supply systems and the excellent service they give.

We have to be deprived of some things to realize what they mean to us. I have been thinking about our water works and what things would be like if it were to be permanently discontinued, if water no longer came from the faucet. The pictures aren't so rosy.

First, I would have to line up a source of water, for I could live but a few days without it. I would have to drill a well, collect rain water, or carry from a stream, pond or spring. At the best it would be a lot of expense or a lot of effort.

I would have to arrange to dispose of the sewage of my household. Again I run into expense and unpleasant conditions which are not nice to talk about.

It would be considerable more trouble to keep clean. Maybe the historic tub on the kitchen floor would have to be revived.

There would be no definite assurance that I would not be exposed to typhoid fever and other water-borne diseases which were such a scourge only a generation ago.

If my house caught on fire there would be much less chance of saving it and the other houses nearby. My family would not be so safe nor my sleep so peaceful.

Because of increased fire danger my insurance rates would jump, probably more than my total water bill. This is one advantage of water service most of us never think about.

In dry weather my lawn would turn brown and my garden would wilt for lack of water. It would be harder to wash my car, my front walk and even my dog.

After all, maybe we have let many years of "water from a faucet" dull our appreciation of a service which is so vital to our civilization and to our ability to live together in comfort, health and safety.

The Above Folder Was Produced by Ford Meter Box Co. and Supplied Water Departments and Water Companies for Distribution to Consumers with the Water Bills. Many Favorable Comments Were Heard on This Little Folder, the Cover Design Appearing on the Left and the "Message" on the Right.

CORROSION CONTROL BY DEAERATION

By SHEPPARD T. POWELL[1] and H. E. BACON[2]

Baltimore, Maryland

All branches of engineering in which the handling of water is involved have found the corrosion of ferrous materials to be a major problem. Preventive methods have been developed as more detailed knowledge of the corrosion process has been gained. At the present time the mechanism of corrosion under various conditions has been the subject of considerable experimental and theoretical study and is fairly well understood. It is well established that the attack of water upon iron results in a concentration of hydrogen ions at the surface of the metal, which stops the corrosion process under the conditions usually encountered in ordinary water for domestic or industrial use. Dissolved oxygen in the water reacts with this protective hydrogen, which is thus removed, and in consequence permits the attack on the metal to continue. Speller lists the oxygen concentration as first in importance among the factors in corrosion by water in the neutral zone.

Protective Coatings

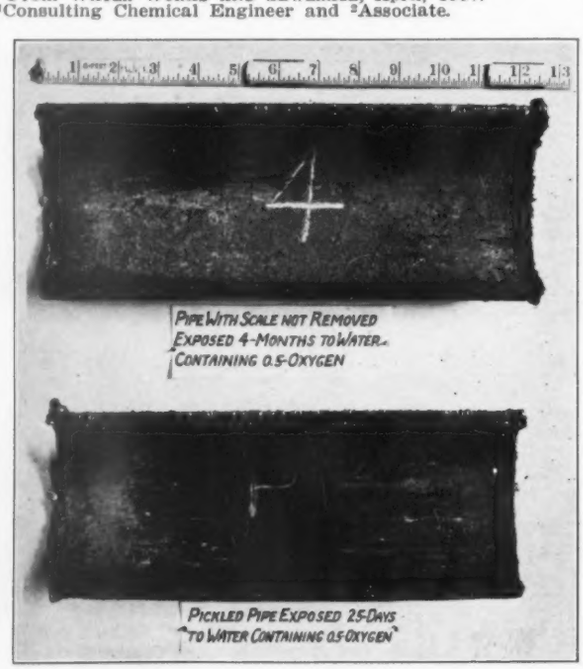
Many methods of corrosion control seek to prevent the water from coming in contact with the metal, by interposing protective layers of various kinds. These may be deposited chemically, as in the case of films which confer passivity on the metal, or scales formed from minerals in the water. Protective coatings and linings are also applied in the form of various paints and cements. Efforts to prevent the corrosion of water mains are generally effected in this way, and when carried out properly such treatment is successful.

Oxygen Removal

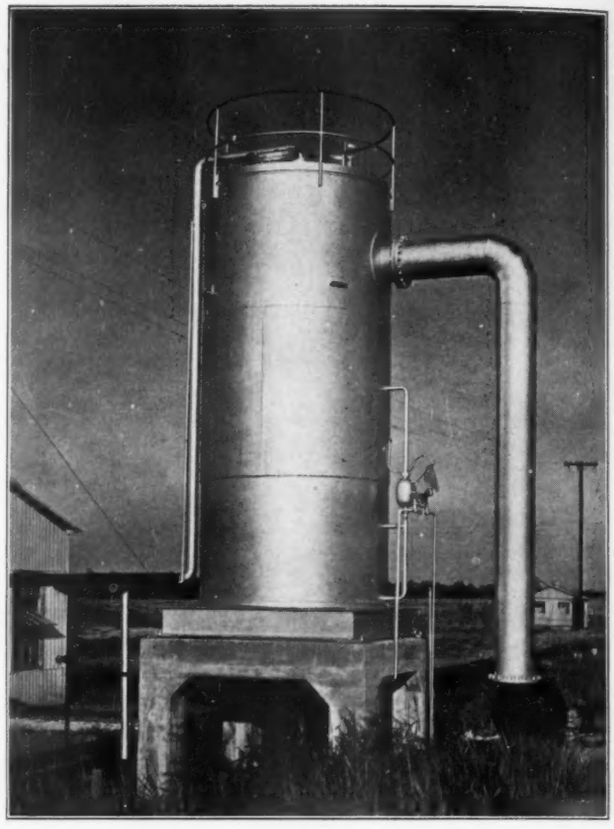
Since dissolved oxygen is generally necessary for the continuous attack of water upon ferrous materials, considerable attention has been given to removal of this gas from water. It is a well-established fact that corrosion of pipes carrying hot or cold water can be enormously curtailed merely by removal of dissolved oxygen from the water. Such treatment is regarded as imperative for boiler feedwater and is accomplished by elevating the temperature, to reduce the solubility of oxygen, and venting the gas which is evolved. Chemical reducing agents are frequently used to complete the deaeration of the water. Hot water heaters have been used to a limited extent for partial deaeration of hot water used in large buildings, and cold water has been deactivated by apparatus which provided for removal of oxygen by contact with scrap iron. However, removal of dissolved oxygen has not been widely practiced except for the deaeration of boiler feedwater.

*From WATER WORKS AND SEWERAGE, April, 1937.

[1]Consulting Chemical Engineer and [2]Associate.



A Dual Demonstration in Corrosion Control. (Below) The Non-Corrosiveness of Deoxygenated Water on Bare Smooth Walled Steel Pipe. (Above) The Effect of Mill-Scale in Increasing Corrosion, Even in the Practical Absence of Dissolved Oxygen and pH Values Approaching 8.2



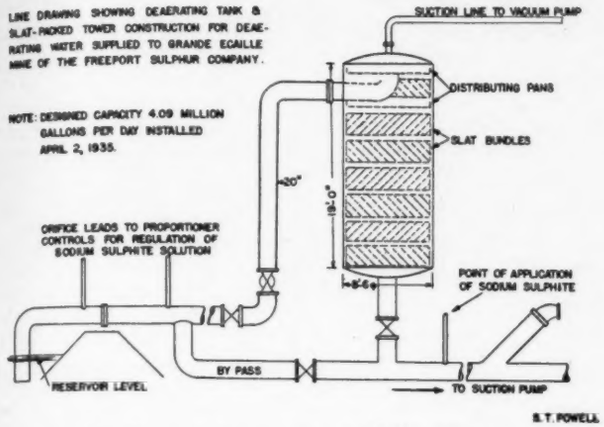
The Completed Deaerator. Capacity 4 *M.G.D. Vacuum* 28 *to* 28.5 *Inches. (For Details and Dimensions, See Sketch)*

Freeport Sulphur Co.'s Problem

The Freeport Sulphur Comany, operating mines in Louisiana and Texas, has encountered the problem of corrosion in connection with its water supply system, and the corrective methods adopted have attracted considerable interest. This company has developed the sulphur resources in the Mississippi delta below New Orleans, with a mine located at Grande Ecaille, Louisiana. Since the sulphur mining process requires large volumes of hot water and it is also necessary to generate considerable steam, an adequate water supply is essential to this industry. This was obtained by establishing a reservoir and pumping station at Port Sulphur, located on the Mississippi river nine miles from the mine. The reservoir water is pumped from here to the property through an uncoated steel pipe. This line is welded and is carried on piles and passes under water only at bayou crossings.

Provision was made for supplying 4,090,000 gallons per day, which was required for operation at the desired rate. However, in four months the carrying capacity of the line decreased nearly 25 per cent due to corrosion of the pipes, which likewise seriously threatened the destruction of the pipe. An examination of the pipe revealed excessive tuberculation, which accounted for the marked rise in the coefficient of friction and consequent depreciated carrying capacity of the line, and increased pumping costs.

Consideration was given to lime treatment to inhibit aggressivity of the water, involving the possibility of producing on the pipe walls a thin protective coating of calcium carbonate. The river water, however, was not susceptible to the precipitation of calcium carbonate by this treatment, because the pH of the settled river water was approximately 8.0, no bicarbonate alkalinity being present most of the time. Sodium silicate was applied in the hope that a silicate scale could be deposited, but evidence


LINE DRAWING SHOWING DEAERATING TANK & SLAT-PACKED TOWER CONSTRUCTION FOR DEAERATING WATER SUPPLIED TO GRANDE ECAILLE MINE OF THE FREEPORT SULPHUR COMPANY.
NOTE: DESIGNED CAPACITY 4.09 MILLION GALLONS PER DAY INSTALLED APRIL 2, 1935.
SUCTION LINE TO VACUUM PUMP
DISTRIBUTING PANS
SLAT BUNDLES
20"
18'-0"
8'-6"
ORIFICE LEADS TO PROPORTIONER CONTROLS FOR REGULATION OF SODIUM SULPHITE SOLUTION
POINT OF APPLICATION OF SODIUM SULPHITE
RESERVOIR LEVEL
BY PASS
TO SUCTION PUMP
S.T. POWELL

Section Through Deaerator and Piping Arrangement

indicated that corrosion continued, or was retarded so little that the treatment was not justified. Further, there was definite evidence that silicate scale was developing in the boilers, and, fearful of consequences, the immediate termination of the silica treatment was determined on.

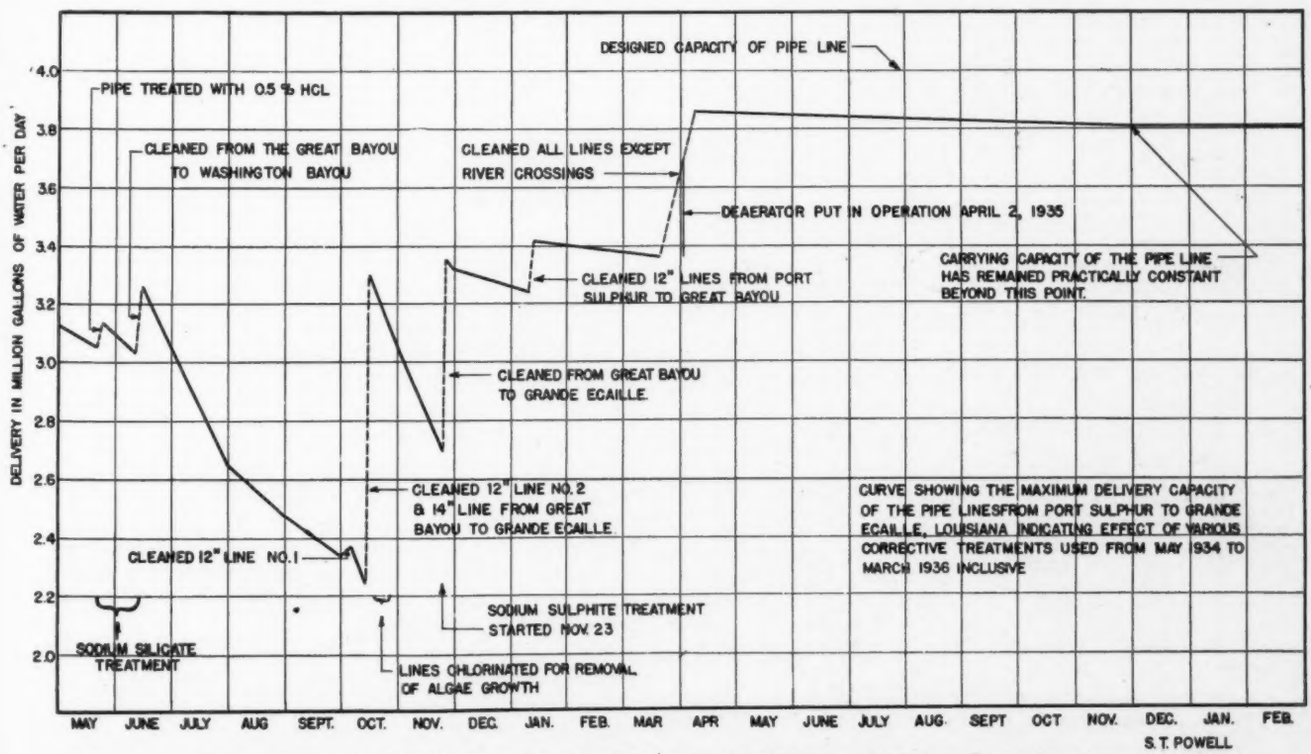
Oxygen Removal Turned to

These experiences led finally to consideration of deaeration of the supply as that treatment which would insure a most overall satisfactory solution of the problem. The oxygen present in the water varied between 6 and 10 parts per million, and exceeded the saturation value at times because of the presence of prolific growths of micro-organisms. Deaeration with sodium sulphite was undertaken experimentally, and almost immediately a reduction was noted in the rate at which the capactiy of the line was decreasing. The expense of chemical deaeration would have been prohibitive, however; and, having served to demonstrate the efficiency of deoxygenation, it was not considered as a permanent treatment. In view of the proven benefits of dissolved oxygen removal, steps were taken to design equipment for mechanically deaerating the water by passing it through an evacuated chamber.

The only previous large-scale application of the deaeration process had been at Coolgardie, Australia, where 6,000,000 gallons of water per day are deaerated to protect a 350-mile pipe line. Inquiries directed to the officials in charge of this latter installation brought the information that excellent results were being obtained, which confirmed statements appearing somewhat earlier in the technical literature. As a result of the investigation and the favorable record of the Australian plant, a cold water deaerator was designed. This consisted of a tower, into the top of which water was to be introduced in the form of a relatively fine spray, dropping into a collecting chamber at the bottom of the unit, from which it could be pumped into the pipe line. The apparatus was to be maintained under a specified vacuum and the gases, flashed from the water, removed by the vacuum pump. An adequate seal was designed so that the desired vacuum could be maintained. Calculations were made to determine the operating characteristics of various designs and the required vacuum pump capacities and cost factors involved in installation and operation.

On the basis of this information a small pilot plant, having a capacity of 100 gallons per minute, was built. This equipment differed from the earlier designed unit in that the tower was packed with wooden slats over which the water trickled in thin films from which gases were readily released. Experiments were made to determine the oxygen removal resulting when the water was dropped from various heights and when different degrees of vacuum were maintained. These tests showed that approximately 95 per cent oxygen removal from the water was effected [0.33 p.p.m residual oxygen] when the deaerating chamber was under a vacuum of 28.5 inches. The curve of oxygen removal becomes almost horizontal at this vacuum and further reduction in pressure requires rapidly increasing pump capacity because of the much larger volume of the rarified gases under the lower pressure. It was determined that the remaining 5 per cent of dissolved oxygen could, therefore, be removed most practicably and economically by means of the deoxygenating sodium sulphite than by extending the mechanical process. The type of deaerating unit constructed as the pilot plant was a much less expensive form of construction than the Australian apparatus, and, since excellent results were obtained, it was used as the pattern in designing the full-scale plant.

Water deaerated by the pilot plant was passed through a 4-inch discharge line for a period of three months. At the end of this period the line was inspected and sections of the pipe were cut longitudinally. No tuberculation was found, and by comparison with control specimens carrying undeaerated water it was obvious that corrosion was almost entirely inhibited. In each case portions of pipe from which the mill-scale has been removed by pickling were inserted in the line. This was done in order to evaluate the harmful effect of mill-scale on past operation. The pipe which contained mill-scale was much more seriously attacked by water with normal oxygen content than was the pickled (cleaned) speci-


DELIVERY IN MILLION GALLONS OF WATER PER DAY
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
DESIGNED CAPACITY OF PIPE LINE
PIPE TREATED WITH 0.5 % HCL
CLEANED FROM THE GREAT BAYOU TO WASHINGTON BAYOU
CLEANED ALL LINES EXCEPT RIVER CROSSINGS
DEAERATOR PUT IN OPERATION APRIL 2, 1935
CARRYING CAPACITY OF THE PIPE LINE HAS REMAINED PRACTICALLY CONSTANT BEYOND THIS POINT.
CLEANED 12" LINES FROM PORT SULPHUR TO GREAT BAYOU
CLEANED FROM GREAT BAYOU TO GRANDE ECAILLE.
CLEANED 12" LINE NO. 2 & 14" LINE FROM GREAT BAYOU TO GRANDE ECAILLE
CURVE SHOWING THE MAXIMUM DELIVERY CAPACITY OF THE PIPE LINES FROM PORT SULPHUR TO GRANDE ECAILLE, LOUISIANA INDICATING EFFECT OF VARIOUS CORRECTIVE TREATMENTS USED FROM MAY 1934 TO MARCH 1936 INCLUSIVE
CLEANED 12" LINE NO. 1
SODIUM SULPHITE TREATMENT STARTED NOV. 23
SODIUM SILICATE TREATMENT
LINES CHLORINATED FOR REMOVAL OF ALGAE GROWTH
MAY JUNE JULY AUG SEPT. OCT. NOV. DEC. JAN. FEB. MAR APR MAY JUNE JULY AUG. SEPT OCT NOV. DEC. JAN. FEB.
S.T. POWELL

History of Carrying Capacity of 9-Mile Water Supply Main Showing Efficiency of Various Corrective Measures Applied

men. With deaerated water, however, the corrosion was very slight, even in the presence of mill-scale, although it was apparent that pickling had been of some benefit in this case also.

Plant Scale Installation

Observations on the pilot plant and calculations for a full-scale unit were so encouraging that a large deaerator was constructed, capable of treating the entire supply of 4,000,000 gallons per day, for which the pipe line was designed. The deaerating apparatus is illustrated in the accompanying sketch and photograph. It will be noted that the vacuum maintained is sufficient to draw the water from the reservoir into the deaerator. The water is distributed over the slat bundles by two perforated pans and is discharged to the suction of the pump feeding the pipe line. Sodium sulphite is applied at a point between the deaerator and the pumps. This chemical is fed by means of a Cochrane proportioner. The water is pumped through the 9-mile line by three 10x8-inch HYC two-stage Allis-Chalmers centrifugal pumps. A Worthington 18x7-inch dry vacuum pump, with an overall efficiency of 39 per cent, is used for maintaining a vacuum of 28 to 28.5 inches in the deaerating tower.

Results of Treatments

The result of this treatment and the entire history of the pipe line are strikingly illustrated in the chart picturing carrying capacities. It will be noted that since the deaerator was put into operation in April, 1935, decrease in carrying capacity has occurred at a very slow rate, and at the present time this curve has become practically horizontal. The pipe line has been inspected at several points and it is apparent that tuberculation has been almost entirely stopped. It is therefore believed that deaeration of the cold water is an entirely satisfactory solution to the very serious problem with which this company was faced. Moreover, this installation has afforded a practical demonstration of the feasibility of mechanically deaerating even large quantities of cold water where the protection of pipes of ferrous material is desired.

Acknowledgment.—We wish to express our appreciation of the assistance and co-operation of W. T. Lundy, vice-president and general manager, and Homer S. Burns, vice-president, of the Freeport Sulphur Company, which have made the project a success and this article possible.

Relative Carrying Capacities of Pipe Lines of Equal Smoothness

Prepared by Emil L. Neubling for the Reading Meter Repair Co.

Diameter of Pipes	⅛	¼	⅜	½	¾	1	1¼	1½	2	2½
26										348.81
24										285.55
22										229.20
20									316.23	181.02
18									243.00	139.10
16								371.60	181.02	103.62
15								316.23	154.05	88.18
14							419.80	266.13	129.64	74.21
12							285.55	181.02	88.18	50.48
10						316.23	181.02	114.76	55.90	32.00
9						243.00	139.10	88.18	42.96	24.65
8					371.60	181.02	103.62	65.69	32.00	18.32
7					266.13	129.64	74.21	47.05	22.92	13.12
6					181.02	88.18	50.48	32.00	15.59	8.92
5				316.23	114.76	55.90	32.00	20.29	9.88	5.66
4½				243.00	88.18	42.96	24.65	15.59	7.59	4.35
4			371.60	181.02	65.69	32.00	18.32	11.61	5.66	3.24
3½			266.13	129.64	47.05	22.92	13.12	8.32	4.05	2.32
3			181.02	88.18	32.00	15.59	8.92	5.66	2.76	1.58
2½		316.23	114.76	55.90	20.29	9.88	5.66	3.59	1.75	1.00
2		181.02	65.69	32.00	11.61	5.66	3.24	2.05	1.00	
1½		88.18	32.00	15.59	5.66	2.76	1.58	1.00		
1¼	316.23	55.90	20.29	9.88	3.59	1.75	1.00			
1	181.02	32.00	11.61	5.66	2.05	1.00				
¾	88.18	15.59	5.66	2.05	1.00					
½	32.00	5.66	2.05	1.00						
⅜	15.59	2.76	1.00							
¼	5.66	1.00								
⅛	1.00									

Diameter of Pipes	3	3½	4	4½	5	6	7	8	9	10
48			498.83	371.60	285.55	181.02	123.13	88.18	65.69	50.48
46			448.48	334.09	256.73	162.75	110.70	79.10	59.06	45.38
44			401.31	298.96	229.20	145.63	99.29	70.94	52.85	40.61
42			357.25	243.00	204.50	129.64	88.18	63.15	47.05	36.15
40			316.23	235.57	181.02	114.76	78.06	55.90	41.64	32.00
38		388.41	278.17	207.22	159.23	100.94	68.66	49.17	36.63	28.15
36		339.30	243.00	181.02	139.10	88.18	59.98	42.96	32.00	24.65
34		294.12	210.64	156.92	120.58	76.44	51.99	37.24	27.74	21.32
32		252.76	181.02	134.85	103.62	65.69	44.68	32.00	23.84	18.32
30	316.23	215.10	154.05	114.76	88.18	55.90	38.02	27.23	20.29	15.59
28	266.13	181.02	129.64	96.57	74.21	47.05	32.00	22.92	17.07	13.12
26	221.12	150.41	107.72	80.24	61.66	39.09	26.59	19.04	14.18	10.90
24	181.02	123.13	88.18	65.69	50.48	32.00	21.77	15.59	11.61	8.92
22	145.63	99.29	70.94	52.85	40.61	25.74	17.51	12.54	9.34	7.18
20	114.76	78.06	55.90	41.64	32.00	20.29	13.80	9.88	7.36	5.66
18	88.18	59.98	42.96	32.00	24.65	15.59	10.60	7.59	5.66	4.35
16	65.69	44.68	32.00	23.84	18.32	11.61	7.90	5.66	4.21	3.24
15	55.90	38.02	27.23	20.29	15.59	9.88	6.72	4.81	3.59	2.76
14	47.05	32.00	22.92	17.07	13.12	8.32	5.66	4.05	3.02	2.32
12	32.00	21.77	15.59	11.61	8.92	5.66	3.85	2.76	2.05	1.58
10	20.29	13.80	9.88	7.36	5.66	3.59	2.44	1.75	1.30	1.00
9	15.59	10.60	7.59	5.66	4.35	2.76	1.83	1.34	1.00	
8	11.61	7.90	5.66	4.21	3.24	2.05	1.40	1.00		
7	8.32	5.66	4.05	3.02	2.32	1.47	1.00			
6	5.66	3.85	2.76	2.05	1.58	1.00				
5	3.59	2.44	1.77	1.30	1.00					
4½	2.76	1.83	1.34	1.00						
4	2.05	1.40	1.00							
3½	1.47	1.00								
3	1.00									

Diameter of Pipes	12	14	15	16	18	20	22	24	26	28
48	32.00	21.77	18.32	15.59	11.61	8.92	7.03	5.66	4.63	3.85
46	28.77	19.57	16.47	14.02	10.44	8.02	6.32	5.09	4.16	3.46
44	25.74	17.51	14.71	12.54	9.34	7.13	5.66	4.55	3.73	3.10
42	22.92	15.59	13.12	11.16	8.32	6.39	5.04	4.05	3.32	2.76
40	20.29	13.80	11.61	9.88	7.36	5.66	4.46	3.59	2.94	2.44
38	17.84	12.14	10.21	8.69	6.48	4.98	3.92	3.15	2.58	2.17
36	15.59	10.60	8.92	7.59	5.66	4.35	3.43	2.76	2.26	1.83
34	13.51	9.19	7.74	6.58	4.90	3.77	2.97	2.39	1.96	1.62
32	11.61	7.90	6.65	5.66	4.21	3.24	2.55	2.05	1.68	1.40
30	9.88	6.72	5.66	4.81	3.59	2.76	2.17	1.75	1.43	1.19
28	8.32	5.66	4.76	4.05	3.02	2.32	1.83	1.47	1.20	1.00
26	6.91	4.70	3.96	3.37	2.51	1.93	1.52	1.22	1.00	
24	5.66	3.85	3.24	2.76	2.05	1.58	1.24	1.00		
22	4.55	3.10	2.61	2.22	1.65	1.27	1.00			
20	3.59	2.44	2.05	1.75	1.30	1.00				
18	2.76	1.83	1.58	1.34	1.00					
16	2.05	1.40	1.18	1.00						
15	1.75	1.19	1.00							
14	1.47	1.00								
12	1.00									

Diameter of Pipes	30	32	34	36	38	40	42	44	46	48
48	3.24	2.76	2.37	2.05	1.80	1.58	1.40	1.24	1.11	1.00
46	2.91	2.48	2.13	1.85	1.61	1.42	1.26	1.12	1.00	
44	2.61	2.22	1.91	1.65	1.44	1.27	1.12	1.00		
42	2.32	1.97	1.70	1.47	1.28	1.13	1.00			
40	2.05	1.75	1.50	1.30	1.14	1.00				
38	1.81	1.54	1.32	1.14	1.00					
36	1.58	1.34	1.15	1.00						
34	1.37	1.16	1.00							
32	1.18	1.00								
30	1.00									

The foregoing tables will be found useful in proportioning distribution lines.

Example: To find how many one-half inch pipes can be supplied by a 4-in. line, follow down the ½-in. vertical column to the number opposite 4-in. diameter of the first column, where the number 181.02 is found, which is the number of one-half inch lines that can be supplied by a 4-in. line.

Example: To find how many 12-in. lines can be supplied by a 48-in. line, follow horizontally along the 48-in. diameter of the first column, until you reach the 12-in. vertical column, where the number 32 is found, which is the result desired.

BATTERY METERS—THEIR INSTALLATION AND PERFORMANCE

By C. M. McCORD

General Superintendent, Water Department, Memphis, Tenn.

In view of what appears to be possible advantages to be had by using a battery of three 2-inch disc meters, instead of a single compound or turbine meter, an investigation was made as to the most practical and satisfactory method of installing or piping them. To begin with, standard fittings were used to build up the two manifolds. The center fitting in each case was a cross with nipples and ells on both sides of the crosses. Between these made up manifolds, the three meter legs were built up, each leg including a 2-inch disc meter with flange couplings ahead and back of the meter, and 2-inch gate valves between the flanges and the manifolds. It was found to be a difficult job to run these three short legs in between the two fixed manifolds. Each leg must make up the same length and the alignment must be practically perfect. While it is not an impossible job, it is one that is slow and difficult. After this set-up was made it was apparent that the meter vault should be large enough to include the manifolds so that they could be inspected and repaired if necessary.

To simplify the installation, both as to fittings and labor, and to provide manifolds that could be built into the vault walls,

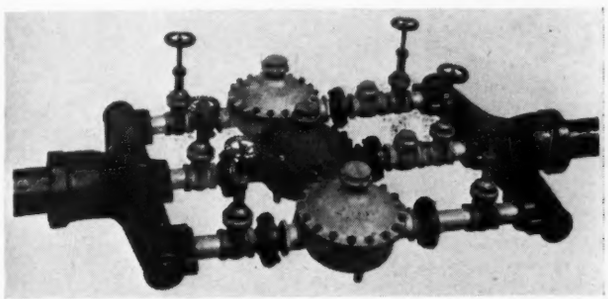


Fig. 1.—Battery Meter Arrangement Designed for Memphis, Tenn. Note special C. I. manifolds and check valve arrangement causing all minor flows to register through one meter.

two cast iron manifolds were made, each having a 4 inch bell inlet and three 2 inch bell outlets properly spaced for the connecting meter legs. The advantages of these cast manifolds are, first: Being cast iron, it is possible to incorporate them in walls of the vault thereby reducing the size of the vault; second: It is not necessary to set them an exact distance apart, nor is it necessary that they be in exact alignment; third: The meter legs, including meter, flanges, check valve and valves are made up at the shop and should they vary as much as an inch in length, they can be readily installed. After the manifolds have been set a measured distance apart, to install the meter leg, one of the flange couplings is taken loose, dividing the leg into two sections. One section is then placed into the bell of one manifold and the second section is placed into the bell of the other manifold. The flange joint is remade, the leg adjusted to position laterally and caulked in place with a small amount of lead wool. After the three legs have been installed in this manner, then the bell joints are poured and caulked in the usual manner. By cutting a light running thread on the 2 inch nipples that are caulked, this prevents them blowing out when a meter is removed and also makes it possible to screw this nipple into and out of the lead joint should it become necessary.

In this test installation, check valves were placed in two meter legs for the purpose of protecting these two meters from hot water and to direct all very small flows to one meter only, rather than have it divide between the three. The accompanying photograph (Fig. 1) shows quite clearly the installation as made by using cast iron manifolds.

Testing for Accuracy

After developing a practical and easy method of making the installation, it was then decided that tests would be run to find

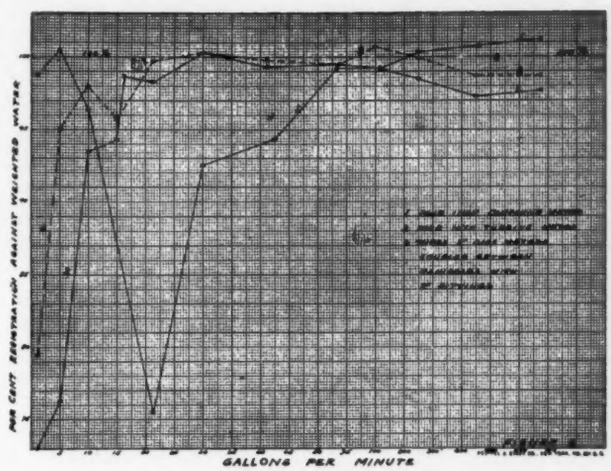


Fig. 2.—Compound of Accuracy of Meter Registration. (Battery Meters vs. Compound vs. Turbine Meters.)
Curve 1—Four inch compound meter.
Curve 2—Four inch turbine meter.
Curve 3—Three, 2 inch disc meters coupled in parallel battery.

out what *our* meters would do under *our* observation. Meters were taken from our shop that were pronounced ready for service. Back of the battery meters pictured, was placed a 4 inch compound meter and back of this a 4 inch turbine meter. This was a series arrangement, water passing through the three measuring arrangements and into a large scale tank, thus making it possible to readily compare the registration of each device against dead weight. Figure 2 shows the results of these tests, rate of flow being plotted on the X axis and percentage of registration on the Y axis. These curves have not been ironed out in anyway and the small circles are the actual results plotted. They may not be the curves that some might expect, but, nevertheless, they represent what happened when *we* tested *our* meters.

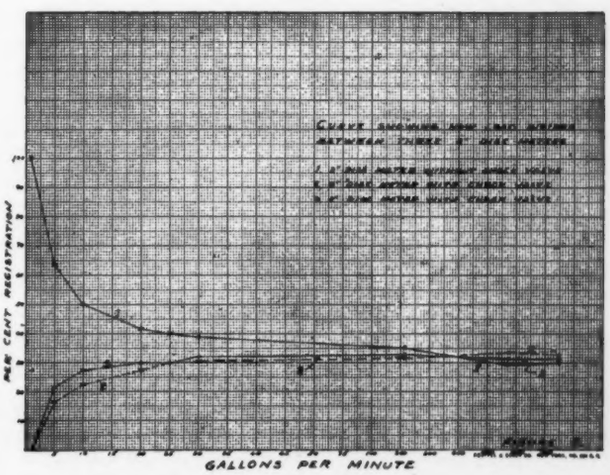


Fig. 3.—Division of Load Between Three 2-inch Meters in Battery. (Note that check valves throw all flow under 5 g.p.m. to the one meter without a check.)
Curve 1—Two in. disc meter without check valve.
Curve 2, Curve 3—Two in. disc meters with check valves.

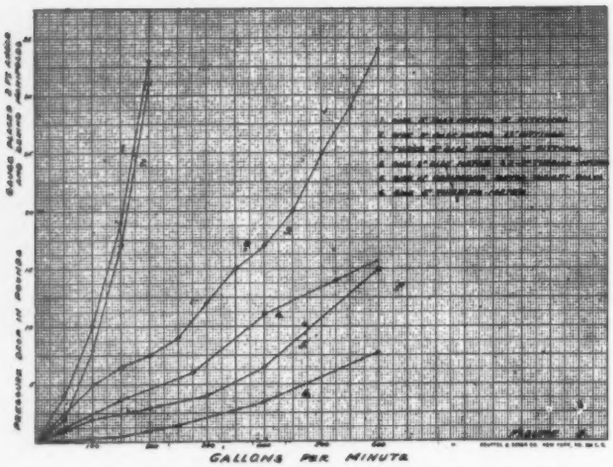


Fig. 4.—Curves Indicating Comparison of Pressure Drop Through Battery Meters vs. Other Types. (Note: Where pressure loss can not be tolerated turbine and compound type meters must be selected at the expense of low flow inaccuracies.)

Curve 1—One 2 in. disc meter with 2 in. fittings.
Curve 2—One 2 in. disc meter with 2½ in. fittings.
Curve 3—Three 2 in. disc meters with 2 in. fittings.
Curve 4—One 2 in. disc meter and two 2 in. turbine meters.
Curve 5—One 4 in. compound meter—weight valve.
Curve 6—One 4 in. turbine meter.

An investigation was then made to determine how the load would divide between the three 2 inch disc meters that made up the battery. Figure 3 plainly shows the result of this test. The number one meter, without check valve, took the small flow entirely and as the flow was increased it shared the load in an increasing amount with the other meters until the flow was about evenly divided. It was also established that on removing the two check valves and operating all three meters without these valves, that one meter took the very small flows. With the checks out, first one meter and then another would register, but with check valves in two legs, the small flow was always registered by the meter without the check.

The last phase of the investigation covered the drop in pressure. This was measured in the case of the battery meters about 2 ft. ahead of and behind the manifolds, and about the same distance ahead and behind the two larger meters. The results obtained are shown in Figure 4, which is self explanatory. After these tests were made, we piped one of the disc meter legs with 2½ inch nipples and valves, and from the figure it will be seen that the drop in pressure was not helped greatly. An examination of this data indicates clearly that different conditions and circumstances demand different methods of metering. In some cases, it may prove necessary to sacrifice small flow registration in favor of increased pressure. In other cases, the small flows can be picked up at the expense of loss in pressure at the larger flows. On these considerations the most desirable arrangement can be selected and the service metered accordingly.

CHECKING WATER HAMMER*

When the water flowing through a pipe is stopped very suddenly there is rise in pressure in the pipe line that may at times amount, roughly, to 50 times the velocity in feet per second at which the water is moving at the instant.

The best cure for water hammer is a slow-closing valve. The next best cure is to provide an air chamber located as close as possible to the valve. If kept fully charged, an air chamber is considered to be of sufficient size when its capacity is one per cent of the pipe line it serve to cushion. Means of renewing the air cushion must be provided for.

Required Volume of Air Chamber

The size, that is, the volume, of an air chamber depends upon a number of factors of which the principal ones are:

The length and size of pipe that the air chamber serves.

The rate of flow of water through this pipe.

The pressure in the air chamber immediately preceding the stopping of the flow, and the pressure due to the stopping of the flow, and,

The nature of the action that puts the air chamber into service—whether it be instantaneous, or rapid, or prolonged.

The following treatment is based upon the first three factors. With reference to the fourth factor—it is the more or less instantaneous stopping of the flow that makes necessary the use of an air chamber. Hence, we are virtually assuming the condition of rapid closing. By this method a volume of air chamber is determined such that the energy of the moving water is absorbed between prescribed limits of pressure in the air chamber.

We have the expression,

$V = L \times P \times R^2$, in which

V is the internal volume of the air chamber in cubic inches,

L is the value from Table 59 for the size and length of pipe that the air chamber serves,

P is the value from Table 60 for the flowing pressure and the assumed maximum pressure, both in the air chamber, and

R^2 is the square of the rate of flow through the pipe in gallons per minute immediately before the stopping of flow.

Note—The flowing pressure can be determined approximately by deducting from the static pressure at the air chamber the loss of pressure in the run of piping (for which the size of an air chamber is being found) under the assumed rate of flow.

Determine the size of an air chamber for a ¾-inch branch, 20 feet long, carrying 10 gallons per minute, based on pressures of 20 pounds per square inch flowing, and 60 pounds per square inch maximum.

Substituting,

$V = 0.042 \times 1.6 \times 10^2 = 6.7$ cubic inches.

Having determined the volume of the air chamber, it becomes necessary to fix the proportions—whether to make it of relatively small diameter and correspondingly long, or short and "dumpy." If made of ¾-inch pipe, length would be 6.7/0.53, or 12.6 inches. Sectional area of ¾-inch pipe is 0.53 square inch from Table 61.

TABLE 59
Values of L

Length of Run, Feet	Size of Pipe, Iron Pipe Size ½	¾	1	1¼	1½	2	2½	3	4
10.....	.037	.021	.013	.0074	.0055	.0033	.0023	.0015	.0009
20.....	.074	.042	.026	.015	.011	.0066	.0045	.0030	.0017
30.....	.111	.063	.039	.022	.016	.010	.0068	.0045	.0026
40.....	.148	.084	.052	.030	.022	.013	.0091	.0060	.0035
50.....	.185	.105	.065	.037	.027	.017	.011	.0075	.0044
60.....	.222	.126	.078	.044	.033	.020	.014	.0090	.0052
80.....	.296	.168	.104	.059	.044	.026	.018	.012	.0070
100.....	.370	.210	.130	.074	.055	.033	.023	.015	.0087
125.....	.462	.262	.162	.093	.068	.041	.028	.019	.011
150.....	.555	.315	.195	.111	.082	.050	.034	.023	.013
200.....	.740	.420	.260	.148	.109	.066	.045	.030	.017
250.....	.924	.524	.324	.185	.136	.082	.057	.037	.023

Note that for each size of pipe value of L is proportional to length of run.

TABLE 60
Values of P

Maximum Pressure, Lb. Sq. In.	Flowing Pressure, Lb. Sq. In. 15	20	25	30	35	40	50	60	80	100
20..	42.									
25..	12.	56.								
30..	6.0	16.	72.							
35..	3.8	7.8	20.	90.						
40..	2.6	4.8	9.8	25.	110.					
50..	1.6	2.5	4.2	7.3	14.	36.				
60..	1.1	1.6	2.5	3.8	6.0	10.	49.			
80..	0.67	0.92	1.3	1.7	2.4	3.3	6.9	18.		
100..	0.48	0.63	0.82	1.1	1.4	1.8	3.0	5.4	27.	
120..	0.37	0.47	0.60	0.75	0.93	1.2	1.8	2.8	8.0	39.

TABLE 61
Sectional Area of Pipe

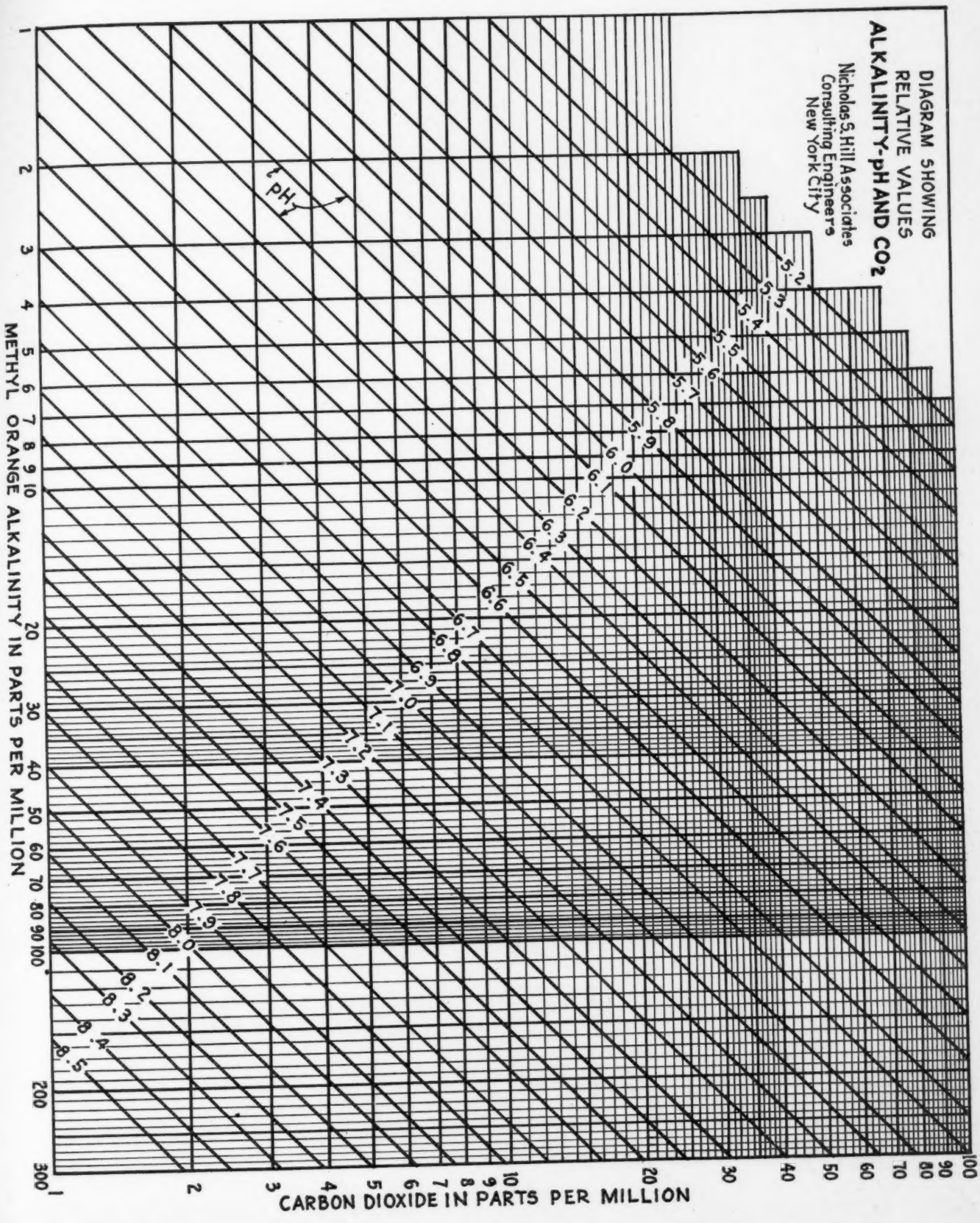
Size of Pipe Iron Pipe Size	Area of Internal Cross-Section of Pipe Sq. In.
½	0.30
¾	0.53
1	0.86
1¼	1.50
1½	2.04
2	3.36
2½	4.78
3	7.39
4	12.7

(The above article should be useful in meter shop practice and otherwise, where quick closing valves must be employed.—*Ed.*)

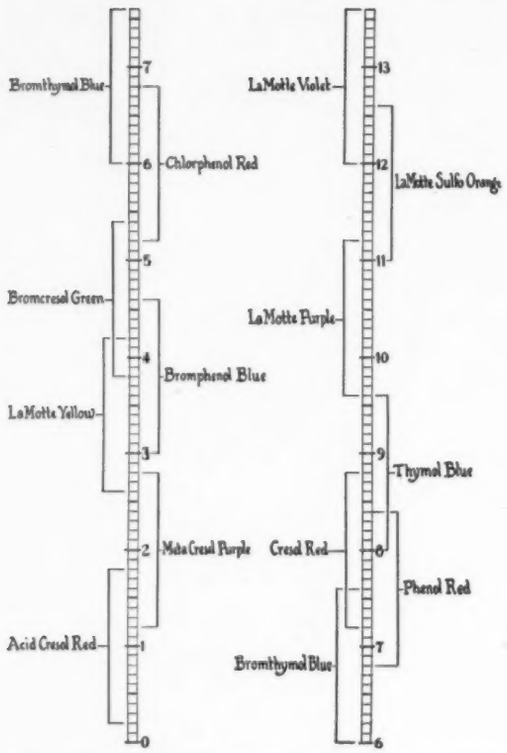
*From "Water Supply in Buildings," by Alex. W. Moseley, Mass. Inst. of Technology, 1935.

RELATIVE VALUES ALKALINITY-pH AND CO_2

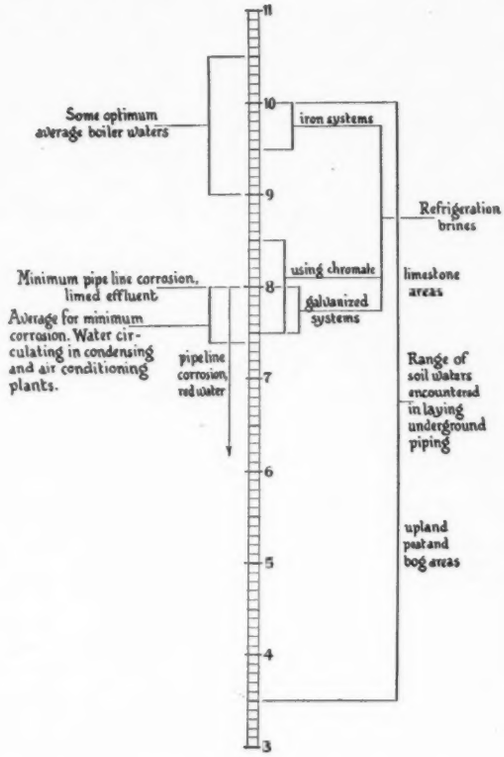
Nicholas S. Hill, Associates



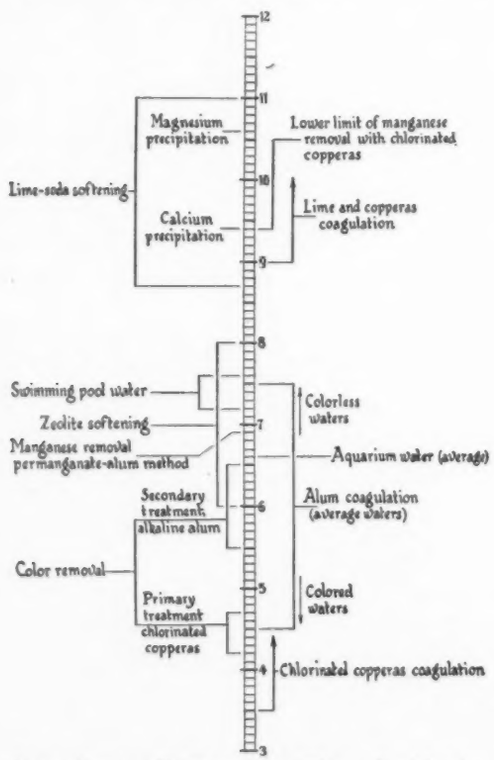
pH ZONES OF IMPORT IN WATER SUPPLY AND SEWAGE TREATMENT PRACTICE *



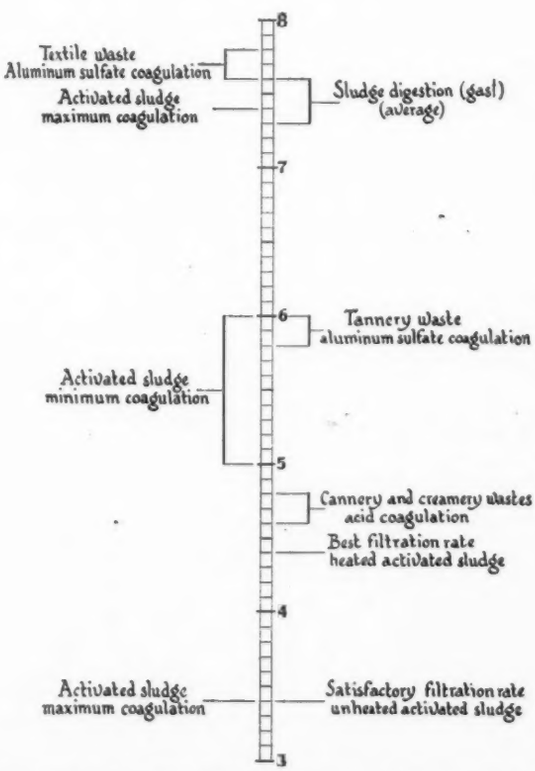
Ranges of Selected Indicators for pH Determination


Some optimum average boiler waters
iron systems
Refrigeration brines
using chromate
limestone areas
galvanized systems
Minimum pipe line corrosion, limed effluent
Average for minimum corrosion. Water circulating in condensing and air conditioning plants.
pipeline corrosion, red water
Range of soil waters encountered in laying underground piping
upland peat and bog areas

Approximate pH Zones Encountered in Common Corrosion Problems



Approximate pH Zones for Water Purification


Textile waste Aluminum sulfate coagulation
Activated sludge maximum coagulation
Sludge digestion (gas!) (average)
Tannery waste aluminum sulfate coagulation
Activated sludge minimum coagulation
Cannery and creamery wastes acid coagulation
Best filtration rate heated activated sludge
Activated sludge maximum coagulation
Satisfactory filtration rate unheated activated sludge

Approximate pH Zones for Treatment of Sewages and Some Industrial Wastes

*Reproduced from the reference work "pH and Its Practical Application"—LaMotte, Kenny & Reed—(Williams and Wilkins, Publishers, Baltimore, Md.)

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(Amongst the most modern of the coagulants are the ferric salts. The most economical source as a ferric coagulant is ferrous-sulphate oxydized with liquid chlorine—i.e., "Chlorinated-Copperas".)

IN SEWERAGE TREATMENT

For Sewerage Treatment, we wish to call your attention to a well-known authority* and his published reasons* for selecting Chlorinated-Copperas, as a coagulant.

1—Chlorinated-Copperas proved to be the cheapest coagulant to produce desired results under existing conditions.

2—The reaction between Copperas and Chlorine proved to be practically instantaneous and required no close control or complicated apparatus—a slight excess of Chlorine being added along with the Copperas for sterilization.

3—Chlorine and Copperas were both easily applied through commonplace equipment and did not present any corrosion problems beyond those experienced in water purification.

4—Chlorinated-Copperas is desirable as a coagulant because of ease of handling, low cost, and ease of application.

IN WATER TREATMENT

Summarizing the experiences with Chlorinated-Copperas in a large city another well-known and proficient manager* states in a published article* the following conclusions:

1—That it is an excellent cold water coagulant.

2—That it has reduced operating costs.

3—That it produces benefits, with no unfavorable results.

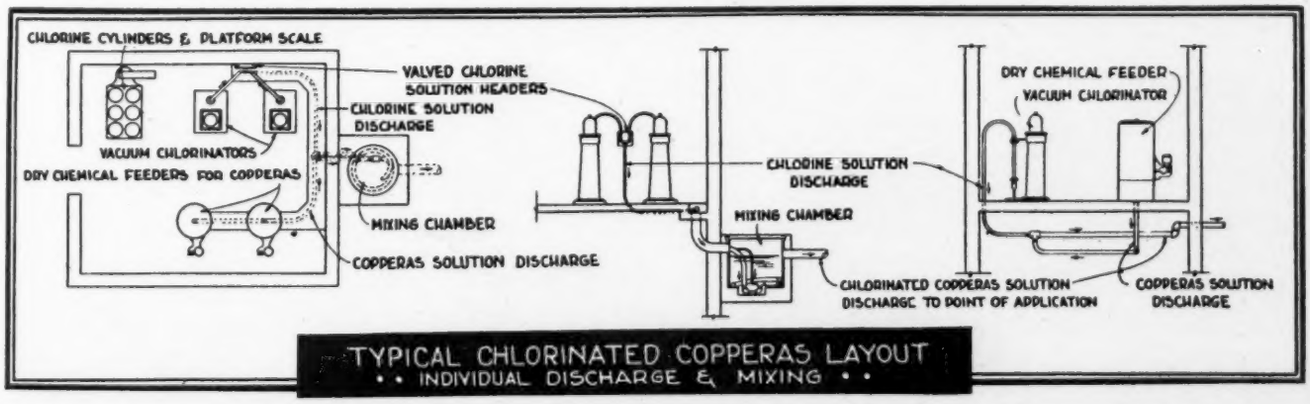
*(References to articles and authors' names available upon request).

KILLING ROOTS IN SEWERS WITH COPPER SULPHATE

Root troubles in sewers can be eliminated by the use of Copper Sulphate. Cities and towns have used copper sulphate for this purpose for several years. By throwing in the copper sulphate crystals into choked sewers, while at least some sewage is still flowing, a sufficient concentration of the poison kills the "feeder" stem and the root mass breaks the dead stem which has lost its toughness. Down sewer go the root balls to its outlet.

ALGAE CONTROL

Copper Sulphate has long been recommended by leading water works engineers, when slime, scum or other effects of algae and undesirable micro-organisms give trouble. Easiest algicide to use, no special equipment or training required.



TYPICAL CHLORINATED COPPERAS LAYOUT
•• INDIVIDUAL DISCHARGE & MIXING ••

WATER SOFTENING*

by CHAS. P. HOOVER
Columbus, Ohio

The consumer judges water to be hard if much soap is required to produce a lather, and soft if it lathers freely. The hardness of most water supplies is due to four compounds which are held in solution. These compounds are:

1. Calcium bicarbonate (solution of limestone, $CaCO_3$, in waters containing carbon dioxide, CO_2).
2. Magnesium bicarbonate (solution of magnesite, $MgCO_3$, in waters containing carbon dioxide, CO_2).
3. Calcium sulphate (in the form, $CaSO_4.2H_2O$, is known as gypsum).
4. Magnesium sulphate (in the form, $MgSO_4.7H_2O$, is known as epsom salts).

As long as any of these compounds or a combination of them are present in a water supply it is hard.

Chlorides and nitrates of calcium and magnesium are sometimes present.

Calcium and magnesium bicarbonates were formerly designated as temporary hardness, but are now termed carbonate hardness.

Calcium and magnesium sulphates, chlorides, and nitrates were formerly designated as permanent hardness or incrustants, but are now usually called non-carbonate hardness.

Water softening processes remove objectionable iron compounds and manganese as well as hardness.

In general terms, hard water is made soft by a treatment which changes calcium and magnesium compounds from a soluble to an insoluble form, and then by removing the insoluble compounds by sedimentation and filtration, or by an exchange process, which consists in replacing the calcium and magnesium with sodium. The first process is known as the chemical, or lime-soda process, and the second, the zeolite process.

[Elsewhere in this issue appears a map of the United States which reveals the average hardness of public water supplies of important American municipalities, of each State.—*Ed.*]

History

The art of water softening with lime dates back to the year 1766 when Cavendish discovered that the addition of lime to natural water caused a deposition of the carbonates of calcium and magnesium. The proposal to use lime for softening hard water on a plant scale was advanced by Thomas Henry in England about 1800, but it was not until 1841 that water softening on a large scale was developed by Dr. Thomas Clark of Aberdeen, Scotland. He patented the process of adding lime to water to precipitate earthy carbonates held in solution by carbonic acid.

Winnipeg, Canada, built the first municipal plant in 1901. In 1903, the first municipal plant in the United States was built at Oberlin, Ohio.

In 1908, water softening on a larger scale than had hitherto been tried was undertaken at Columbus, Ohio, when a plant having a capacity of thirty million gallons per day (now 50 m.g.d.) was constructed.

For years the advantages of water softening were offset to a certain extent by disadvantages. Difficulties arose in operating sand filters on account of incrustation of the sand with calcium carbonate. Water mains, service pipes and meters became clogged with heavy deposits. When water contained an excess of causticity it was unpalatable. The recarbonation process developed by Archbutt and Deeley in the latter part of the last century, was employed at several plants in England for the purpose of overcoming all the above difficulties, but its first employment in this country, on a successful plant scale, was in 1921 at Defiance, Ohio. Since that time practically all water softening plants have been equipped with recarbonation devices.

The chemistry of water softening is now well understood, and an exact prediction of the results to be obtained can be made. Improvements in design and equipment for applying chemicals and removing sludge all tend toward simplifying operation. As a result of these improvements there has been a decided trend toward some degree of water softening by municipalities throughout the United States. Industry has gone forward with water softening to a far greater extent because of proven economies in processes, materials and equipment where soft water is made available.

Economic Aspects of Water Softening

The water supply in a large number of cities and villages should be softened because:

1. Hard water destroys soap; makes household work more difficult; has a bad effect on clothes washed in it, on plumbing, heating systems, boiler tubes and shells; and is unsuitable for many industries.
2. Softening at a central source of supply rather than in thousands of homes is economically sound.

It is cheaper to pay a reasonable additional charge for centralized softening than to accept a hard supply, a portion of which must be softened in the home. All of us, whether we

*Ecerpts from "Water Supply and Treatment"—written by Mr. Hoover and published by the National Lime Association.

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Infilco equipment is available in types and sizes to meet every requirement of a modern filter plant. Infilco-equipped plants centralize equipment responsibility and assure coordinated results. For the new plant—as well as rebuilding of old plants—Infilco offers:

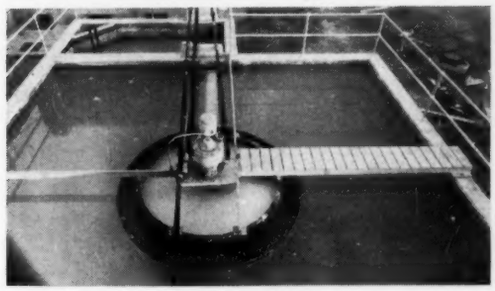
Aerators. Automatic Control Equipment. Chemical Feeders—Dry and Solution Types. Lime Feeders and Slakers. Chemical Proportioners. Coagulators, Clarifiers and Settlers. Filter Operating and Control Tables. Filter Underdrain Systems. Flow Controllers, Indicators, Recorders and Proportioners. Gauges. Hydraulic Valve Controls. Iron and Manganese Removal Plants. Mixing Basin Equipment. Pipe Gallery Specialties. Recarbonating Plants. Sampling and Observation Tables. Taste and Odor Removal Plants. Venturi Tubes and Infilco Meters. Vertical and Horizontal Pressure Filters. Water Level Controllers, etc. Whatever the requirement, you will find that Infilco Equipment has maintained its leadership in design and quality—and has led the way with modern improvements.

AUTOMATIC CONTROLS

Infilco Robotrol Automatic Filter and Softener Operators, Hydraulic Valve Controls, Single Control Valves, Loss of Head and Capacity Alarms and Actuators, etc., furnish means to provide semi-automatic or automatic operation of gravity or pressure water softeners and filters. Infilco Automatic Control Equipment may be installed to modernize, rehabilitate and increase the efficiency of existing filter plants and water softening plants.

ACCELATOR WATER SOFTENERS

The Accelator Water Softener although retaining the advantages of the lime-soda process, represents a revolutionary advance in water softening. It delivers a water of surprisingly low mineral content, low alkalinity, low hardness and low turbidity. Chemicals are applied to the water in a new way and the reactions take place under a new set of conditions. Mixing, reaction, and clarification are all carried out in such incredibly small space that the area of the Accelator is usually no larger than that of the filters.



Accelator Water Softener

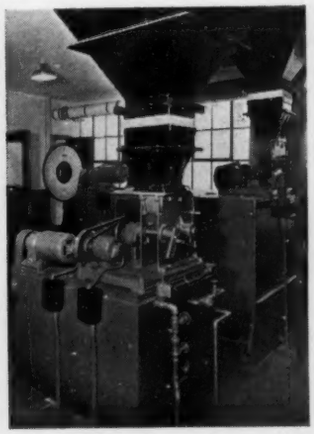
ZEOLITE WATER SOFTENERS

Infilco Zeolite Softeners are built in types and sizes to meet any capacity requirement. They are furnished with any of several types of Infilco high capacity manufactured zeolites or greensand zeolites, to assure economical and efficient softening of various types of waters. Controls are furnished for either manual, semi-automatic, or full-automatic operation, as desired.

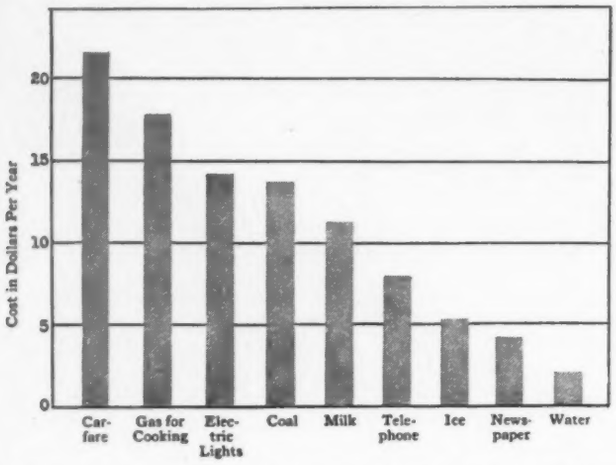
SEWAGE TREATMENT EQUIPMENT

Infilco Activators, Chemical Feeders, Coagulators, Dosing Syphons, Rotary Distributors, Samplers, Settlers, Sludge Pumps, etc., are designed to meet present-day needs in the various types and phases of sewage and trade waste treatment.

Robotrol Operator



Lime Feeders and Slakers



Cost Per Capita Per Year for Domestic Services (Family of Five)

know it or not, soften some water each day, for it is necessary to use soft water to keep clean.

All public water supplies contain some hardness and that portion of the water in which soap is used must be softened to be effective. Soap has very little cleansing action until it lathers and it will not lather until the hardness salts in the water have been neutralized by it.

Aside from the objections of the precipitated soap curd, the extravagance of removing hardness with soap can be appreciated when it is realized that a pound of lime costing approximately one-half cent will neutralize as much hardness as 20 pounds of soap costing approximately $3.00.

Soap Losses Determined Experimentally

The amount of soap consumed and the quantity of water used for household processes, laundering, dish-washing, cleaning, washbowl activities, and bathing, was carefully measured for a period of one week, and calculated for a year.[1] Two kinds of water were used, each for one week: (1) Scioto River water which was filtered and sterilized but not softened. The hardness was 270 parts per million (16 grains per gallon). It was delivered in 10-gallon bottles to the home where the experiments were made. (2) Softened water as delivered to consumers. The hardness averaged about 80 parts per million (4.7 grains per gallon). In the home where the experiments were made there were five people, three adults and two children. Ivory soap in bar and flake form was used, the former costing 21 cents per pound and the latter 31 cents. The laundering was done in a vacuum type electric washer, the weight of the clothes averaging 29 pounds per washing.

Water-works records show that this family used the average quantity of water, about 30 gallons per day per capita. Their bill amounted to 75 cents per month. The soap was dried and weighed before and after it was used, so that the difference in weight would represent the weight actually used. The results for the week figured to one year show:

1. That this family used 281 gallons of water a week for ordinary household cleaning, divided as follows: Laundry, 15 gallons; dish-washing, 73 gallons; cleaning, 4 gallons; bathing, 136 gallons; and washing of hands, 53 gallons.
2. That approximately 11.46 pounds of soap were used per week with unsoftened water, or a total of 596 pounds per year.
3. That approximately 3.7 pounds of soap were used per week with Columbus city softened water, or a total of 192.5 pounds per year.
4. That softened water saved this family 403.5 pounds of soap per year.
5. That this soap, valued at 20 cents per pound, represented a saving of $80.70 per year and figured at 12 cents a pound, the price of cheaper laundry soaps, represented a saving of $48.42.
6. That this consumer could afford to pay five or six times as much for softened as for unsoftened water.

The investigation also disclosed the following facts:

1. One-half again as much time was needed to launder clothes in the unsoftened as with the softened water.
2. The cleanliness of clothes washed in the unsoftened water was not entirely satisfactory. Several very soiled pieces had to be rewashed and all of the clothes had to be re-rinsed.
3. The general appearance of the clothes was unsatisfactory.

These figures may be high for the average family but they are fairly representative for a family of five living in moderate circumstances. There are 55,033 domestic services or consumers in Columbus, Ohio. Applying the above figures, if each one saves $48.42, the total saving would amount to $2,664,697.86. If this figure is divided by two because of the possible use of cheaper compounds to "break" the water, the saving would be $1,332,348.93. This amount is about eight or ten times the cost of chemical softening.

Relations of Soap Wastage to Quantity and Type of Water

The above experiment demonstrated that 8 gallons of water per day per person were used for household processes. This quantity was probably not all completely softened by soap. Other workers have made the following estimates of water completely softened per capita per day:

	Gallons
Foulk[2]	0.9
Report of Special Committee for Madison, Wis.	1.7
City of St. Louis[3]	1.0
Average	1.2

The amount of soap required to reduce the hardness of 1,000 gallons of water, one part per million, has been determined as being 0.2 of a pound (Foulk's formula: Pounds of soap consumed per 1,000 gallons $= 2 + 0.2H$).

Based on these assumptions, the loss per family of five using water of varying degrees of hardness is shown in the following table:

SOAP WASTAGE AND COST WHEN USING WATER HAVING HARDNESS VARYING FROM 150 TO 500 PARTS PER MILLION

Raw water hardness p.p.m	Hardness removed by softening	Hardness reduced to	Loss lbs. of soap per family of five per yr.	Loss per family of five per year*
150	65	85	28.5	$3.40
200	115	85	50.0	6.00
250	165	85	72.5	8.70
300	215	85	94.0	11.30
350	265	85	116.0	13.90
400	315	85	138.0	16.55
450	365	85	160.0	19.20
500	415	85	182.0	21.85

*Soap at 12 cents per pound.

Actual Survey of Retail Soap Sales

The economic effects of quality of water, with special reference to soap consumption in the home, were demonstrated by H. W. Hudson[4] in a field survey of retail soap sales in four cities of the middle west: Superior, Wisconsin, and Bloomington, Champaign-Urbana, and Chicago Heights, Illinois. A canvass of all retail stores selling soap in these cities was made by a personal investigator who compiled a complete record of soap sales. The soap sales and per capita soap consumption with different types of water are shown in the following tables:

TOTAL SOAP SALES IN FOUR CITIES

City	Annual soap sales, pounds	Annual soap sales, dollars
Superior, Wisconsin	1,530,314	$196,133
Bloomington, Illinois	1,517,658	215,528
Champaign-Urbana, Illinois	2,093,881	307,732
Chicago Heights, Illinois	1,009,503	159,910

PER CAPITA SOAP CONSUMPTION WITH DIFFERENT TYPES OF WATER

City	Total hardness of water supply p.p.m.	Annual per capita soap consumption pounds	Annual cost of soap per capita dollars
Superior, Wisconsin	45	29.23	$3.75
Bloomington, Illinois	70	32.13	4.48
Champaign-Urbana, Illinois	298	39.89	5.93
Chicago Heights, Illinois	555	45.78	7.50

[1]Thesis presented for the degree of Master of Science by Miss Pauline Snyder, Ohio State University, 1927.

[2]Geological Survey of Ohio, Bulletin 29, 1925.

[3]Report of Water Commission, 1922.

[4]Abstract of thesis for Doctor of Philosophy in Economics, University of Illinois, 1933.

The results show:

1. That soap bills increase as the hardness of the water with which soap is used increases.
2. That even with a relatively soft water, a considerable quantity of soap is required to remove dirt and grease.
3. That by taking Superior as a basis for comparison, the annual per capita soap waste is: Bloomington, 2.9 lbs.; Champaign-Urbana, 10.7 lbs.; Chicago Heights, 16.6 lbs.
4. That this loss in Chicago Heights would amount to $15.00 per year per family of four.

From the results of this study an equation was formulated to show the degree of hardness necessary in any particular water supply in order that the economy in soap obtainable by the use of soft water would pay for the cost of softening.

$$X = \frac{C - 75D + 75F}{F - D}$$

X = hardness of water supply in p.p.m., the softening of which will be paid for in soap economy alone.
75 = demonstrated attainable hardness of water in p.p.m., from municipal water softening plants.
F = soap waste per capita per year per p.p.m. hardness.
C = capital overhead charges, including superintendence, per capita per year.
D = cost of chemicals per capita per year per p.p.m. hardness.

Mr. Hudson states that if this equation is applied to data for Champaign-Urbana and the hardness of the raw water tested only 145 p.p.m. (it is actually 298 p.p.m.) a municipal water softener that would soften the water to 75 p.p.m. would save enough in soap for home use alone to pay for itself.

Effect of Hard Water on Power and Heating Systems

Heating hard water causes it to deposit scale in water pipes, heating coils, boiler tubes, and boiler shells. The heat loss due to scale, 1/50 to 1/9 inch thick, has been computed to be from 7 to 16 per cent.[5] This means that with scale 1/9 inch thick, 16 cents of every dollar paid for coal is lost. This is in addition to the trouble, cost of drainage, and time lost in getting rid of the scale. According to an estimate of the American Railway Engineering Association,[6] the damage caused by one pound of scale is 13 cents. The Association further estimates that the improvement in operating and maintaining locomotives, due to water softening, amounts to a saving of from $4,000 to $9,000 per locomotive per year.

Hard Water Stultifies Growth of Cities

A study of ten Illinois cities shows[7] that eight have comparatively soft water supplies as judged by midwestern standards, whereas the other two have supplies that are excessively hard. The two hard water cities will be designated as A and B. Both are situated in rich agricutural sections and are advantageously located with respect to large markets. In spite of these advantages they have shown a very slow rate of growth. In 1880, A and B together had 26 per cent of the total population of the ten cities. In 1920 they together had only 13.7 per cent.

Manufacturing industries which require soft water for their successful operation, in establishing plants select communities having satisfactory water, other things being equal.

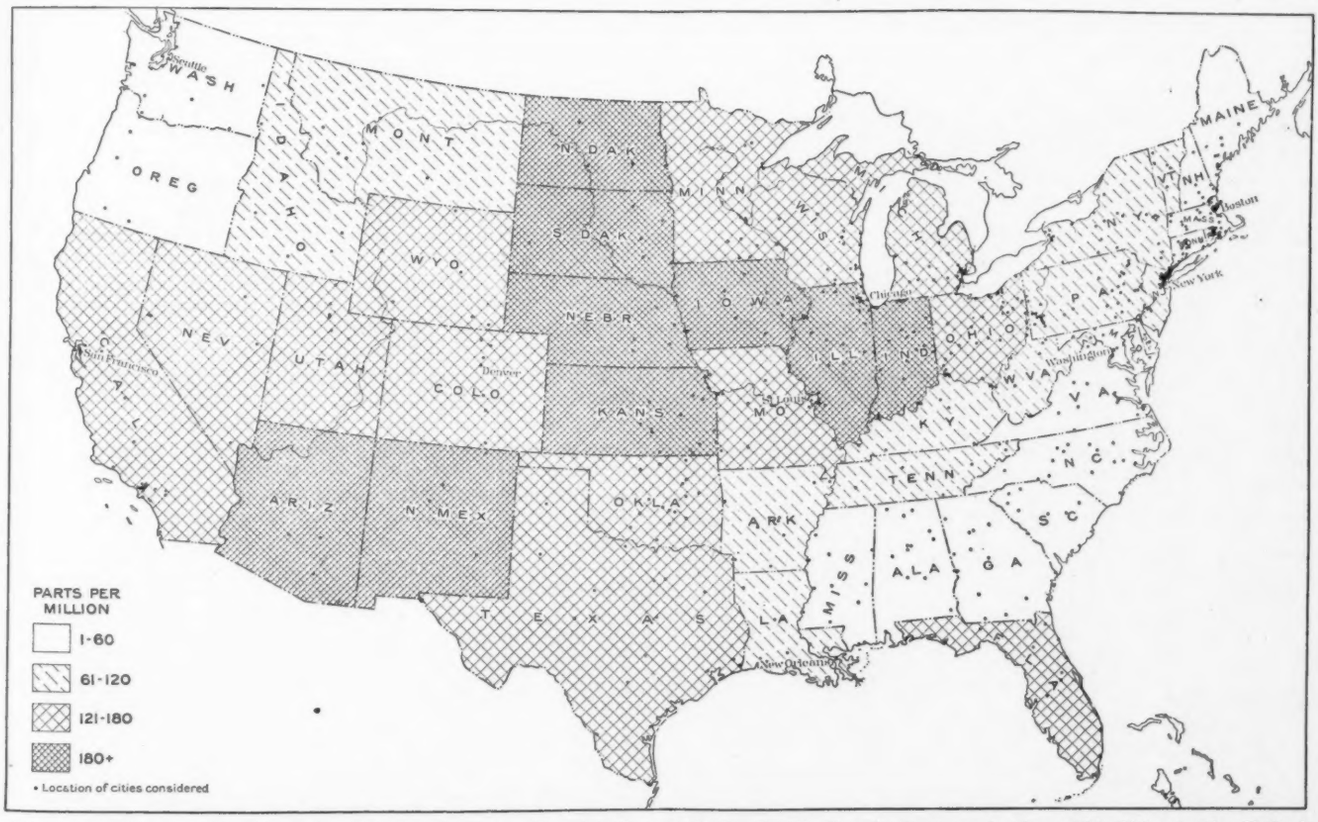
[7]Alvord, Burdick & Howson (Chicago), a private communication.

Cost of Softened Water vs. Other Commodities

"Cheap as dirt" is a common expression, but even expensively treated water is *much* cheaper! Two hundred and forty-one gallons of water equal one ton. Five cents a ton would be a little over 20 cents per 1,000 gallons, which is more than the average consumer pays for water in the larger and medium sized cities. A ton of dirt delivered would cost many times this amount.

The cost per capita per year for various domestic services by a family of five in Columbus, Ohio, is shown in the chart on the preceding page.

[5]U. S. Bureau of Mines, Tech. Paper 218.
[6]Bulletin, American Railway Engineering Association, November, 1923.



Weighted Average Hardness, by States, of Water Furnished in 1932 by Public Supply Systems in Over 600 Cities in the United States (Reprinted from U. S. Geol. Survey Water Supply Paper—658)

CONTROL OF ALGAE

By FRANK E. HALE, Ph.D.

Dept. of Water Supply, New York City

Knowledge of microscopic organisms and their control is one of the more important aspects of water supply practices. Chief amongst agents utilized in algae control is copper sulphate, its application to reservoirs being known as "coppering."

The simplest manner of application is to drag burlap bags, containing about 50 pounds each, through the water by means of rowboats, taking a zigzag course so as to triangulate the surface of the water. Wind, waves, diffusion and gravity admix the streaks of treated water with the remainder. Crude as this method is, it has been found very effective. But it is essential that the chemical be well distributed.

[Recently there has been effectively used by the Los Angeles Water Department a mechanical broadcasting device on the rear of a launch. It distributes pulverized copper-sulphate over the water surface in a manner equivalent to that used in broadcasting fine grass seed. This method reaches shallow shore-line areas most effectively. See Jour. Review, Feby., 1936.]

The reservoir should be partitioned into arms by land sights and the capacity, in million gallons for total depth, calculated for each area so that dosage may be correctly apportioned. In the case of organisms predominating in the upper water, dosage may be calculated on the upper 20-30 feet only. About 3,000 pounds a day may be distributed by a single launch in favorable weather.

Calculation of the volume of a body of water is not difficult. Two formulas should be kept in mind:

One cubic foot contains 7½ gallons.

One gallon of water weighs 8⅓ pounds.

Estimate the area in square feet. Estimate the average depth in feet by soundings. Multiply the two for cubic feet. Multiply cubic feet by 7½ to find gallons and express in million gallons. In the table of treatment which follows one column reads directly in pounds of copper sulphate per million gallons of water to apply for each genus of organisms.

To calculate amount of copper sulphate needed from "Parts per million" column multiply million gallons by 8⅓ to obtain million pounds of water. Multiply this figure by the amount shown in the column headed "Parts per million."

Two formulas are helpful to bear in mind:

1 pound per million gallons = 0.12 part per million.

1.0 part per million = 8⅓ pounds per million gallons.

Copper sulphate may be fed to an aqueduct by continuous dry-feed to destroy organisms feeding from one reservoir to another. The effective dosage is identical with that employed in open reservoirs by the launch method.

Another frequently employed method of continuous feed of copper sulphate is by solution feed. On a small scale a wooden bucket may be suspended in the flowing water so arranged that its depth of submersion may be varied. A small hole in the bottom of the bucket admits the water. The bucket is filled with copper sulphate and a definite amount added once or twice a day and the depth of submersion regulated so as to dissolve the determined quantity each day.

Three to four hundred pounds per day may be fed by the barrel arrangement shown. By this equipment the chemical is applied as a saturated solution and the application is very uniform. The barrel is kept constantly full of water from a supply controlled by a float valve with glass ball. From the bottom of the barrel, through rubber, glass and copper tubing, the solution is discharged to the water at the most turbulent point. The flow is regulated by a pinch-cock. The barrel sets on a scale so that the weight of chemical delivered may be checked. The water consumed varies with temperature and other conditions from about 1¼ to 2½ gallons per pound of chemical dissolved.

Copper sulphate is very soluble in water. The following table may be useful in feed regulations at various water temperatures:

SOLUBILITY OF COPPER SULPHATE

Temperature: °C.	°F.	Pounds of Copper Sulphate Crystals ($CuSO_4.5H_2O$) Per 100 lbs. solution.	Per 100 gallons water
0	32	19.5	126.0
10	50	23.1	226.8
20	68	26.9	269.4
25	77	28.9	296.1
30	86	31.3	326.1
40	104	35.2	371.1
50	122	39.1	433.7
60	140	44.5	521.3
80	176	55.5	717.2

Spraying with strong copper sulphate solution is advantageous in some instances, *e.g.*, in shallow bays and on floating masses of certain organisms. For this purpose a spray pump or equipment such as is used with insecticides for trees is available. [An alternate procedure is that used by Los Angeles to mechanically broadcast the pulverized sulphate previously mentioned.—Ed.]

Walls of basins have been sprayed for growths such as Spirogyra, using a 5 per cent solution.

Experience differs with waters of different composition, with temperature, and with amount of organisms present as to the right dosage to apply for each organism. About twice as much chemical is required in winter as in summer. It is a waste of chemical to apply an insufficient amount. If a smaller dosage fails, the entire larger dosage must be applied at one time. The water usually clears within three to four days when the correct quantity has been applied. [See Dosage Tables.] Weeds in general are not killed by copper sulphate. Sometimes fish are killed, but rarely in quantity. The following table indicates the susceptibility of fish to the chemical:

LIMITING SAFE DOSAGE OF COPPER SULPHATE FOR FISH

Fish	Parts per million	Pounds per million gallons
Trout	0.14	1.2
Carp	0.33	2.8
Suckers	0.33	2.8
Catfish	0.40	3.5
Pickerel	0.40	3.5
Gold Fish	0.50	4.2
Perch	0.67	5.5
Sunfish	1.35	11.1
Black Bass	2.00	16.6

Chlorine Treatment

Chlorination is the most valuable adjunct to copper sulphate in control of microscopic organisms. In the first place it helps destroy the odors set free by the copper sulphate treatment. In the second place it destroys may *genera*, in several instances the very ones least affected by copper sulphate.

The use of chlorine in increased dosage has slowly been extended not only to destroy organisms but also the distasteful oils. Experience to date indicates that with soft waters the following effects have been noted:

EFFECTIVE CHLORINE DOSAGES

Organisms Units per cc.	Chlorine ppm. Dose	Residual	Effect— Org. destroyed	Taste destroyed
Synura 1—25	0.3	.05-.10	Yes	Yes
Synura 50—100	0.5-0.7	.20	Yes	Yes
Synura 200	0.7-0.9	.30	Yes	Yes
Uroglena 2,000	0.5	.10	Yes	Yes
Uroglena 6,000	0.5	.10	Yes	No
Dinobryon 500	0.5	.10	Yes	Yes
Asterionella 1,350	0.7	.20	Yes (50%)	No
Aphanizomenon 1,500.	0.7-0.8	.20-.25	Yes (50%)	No

Prechlorination with high dosage, 1 ppm. and higher, is employed now quite extensively in conjunction with filtration to destroy or prevent growth of microscopic organisms in sedimentation and reaction basins and lessen their interference with filtration. Longer filter runs are obtained in addition to lightening the bacterial load upon the filters.

Miscellaneous Data. Cyclotella has been destroyed by dosage of 1 ppm. *Crenothrix* is another troublesome organism which is readily controlled by chlorine or chloramine in dosage of 0.5 ppm. Chlorine in dosage of 0.33 ppm. has readily controlled or prevented formation of jelly masses or fungus slime in well supplies and in mains and prevented clogging of condensers.

Crustacea, such as *Cyclops* and *Daphnia*, have been controlled on occasions. *Daphnia*, red variety, has been controlled with 1 ppm. chlorine and *Cyclops* with 3 ppm. chlorine.

The following table contains data brought up to date on dosages of copper sulphate and dosages of chlorine required for microscopic organisms, including also odors and tastes produced. It is based on published data and personal experience.

CHEMICALS REQUIRED FOR CONTROL OF DIFFERENT GENERA*

Organisms—Odor:	Copper Sulphate[1] Parts per million	Pounds per mil. gals.	Chlorine ppm.
Diatomaceae:			
Asterionella‡ ..... Aromatic, geranium, fishy	0.12*-0.20*	1.0-1.7	0.5*-1.0*
Cyclotella†‡ ..... Faintly aromatic			1.0
Diatoma† ..... Faintly aromatic			
Fragilaria†	0.25	2.1	
Melosira†‡§	0.20*	1.7	2.0
Meridion ..... Aromatic			
Navicula†	0.07	0.6	
Nitzchia§	0.50	4.2	
Synedra†‡ ..... Earthy	0.36*-0.50*	3.0-4.2	1.0
Stephanodiscus	0.33	2.8	
Tabellaria‡ ..... Aromatic, geranium, fishy	0.12*-0.50*	1.0-4.2	0.5*-1.0
Chlorophyceae:			
Cladophora†	0.50	4.2	
Closterium	0.17	1.4	
Cœlastrum†	0.05-0.33	0.4-2.8	
Conferva†	0.25	2.1	
Desmidium	2.00	16.6	
Dictyosphærium‡ ..... Grassy, nasturtium, fishy			0.5*-1.0
Draparnaldia	0.33	2.8	
Eudorina ..... Faintly fishy	10.00	83.0	
Entomophora	0.50	4.2	
Glœocystis ..... Offensive			
Hydrodictyon† ..... Very offensive	0.10	0.08	
Microspora	0.40	3.3	
Palmella	2.00	16.6	
Pandorina ..... Faintly fishy	10.00	83.0	
Protococcus			1.0
Raphidium	1.00	8.3	
Scenedesmus	1.00*	8.3	
Spirogyra†	0.12	1.0	0.7-1.5
Staurastrum	1.50	12.5	
Tetrastrum			1.0
Ulothrix	0.20*	1.7	
Volvox‡ ..... Fishy	0.25	2.1	0.3*-1.0
Zygnema	0.50	4.2	
Cyanophyceae:			
Anabæna‡ ..... Moldy, grassy, vile	0.12*	1.0	0.5*-1.0
Aphanizomenon‡ ..... Moldy, grassy, vile	0.12-0.50*	1.0-4.2	0.5*-1.0*
Clathrocystis ..... Sweet grassy, vile	0.12*-0.25*	1.0-2.1	0.5*-1.0
Cœlosphærium‡ ..... Sweet grassy	0.20*-0.33	1.7-2.8	0.5*-1.0
Cylindrospermum ..... Grassy	0.12	1.0	
Microcystis	0.20	1.7	
Oscillaria†	0.20-0.50*	1.7-4.2	1.1
Rivularia ..... Moldy, grassy			
Protozoa:			
Bursaria ..... Irish moss, salt marsh, fishy			
Ceratium†‡ ..... Fishy, vile, (rusty brown color)	0.33	2.8	0.3*-1.0
Chlamydomonas	0.50–1.0	4.2-8.3	
Cryptomonas ..... Candied violets	0.50	4.2	
Dinobryon‡ ..... Aromatic, violets, fishy	0.18*	1.5	0.3*-1.0
Endamœba histolytica (cysts)			25.0-100.0
Euglena	0.50	4.2	
Glenodinium ..... Fishy	0.50*	4.2	
Mallomonas ..... Aromatic, violets, fishy	0.50	4.2	
Peridinium ..... Fishy, like clam-shells	0.50*-2.00	4.2-16.6	
Synura‡ ..... Cucumber, muskmelon, fishy, bitter taste	0.12*-0.25	1.0-2.1	0.3*-1.0
Uroglena‡ ..... Fishy, oily, cod-liver oil taste	0.05*-0.20*	0.4-1.6	0.3*-1.0
Crustacea:			
Cyclops†‡§			1.0 -3.0
Daphnia†‡§	2.00	16.6	1.0 -3.0
Schizomycetes:			
Beggiatoa† ..... Very offensive decayed	5.00	41.5	
Cladothrix	0.20	1.7	
Crenothrix†‡ ..... Very offensive decayed, medicinal with chlorine	0.33 -0.5*	2.8-4.2	0.5*
Leptothrix†			
Sphaerotilis, natans† .... Very offensive decayed	0.40	3.3	
Spirophyllum†			0.25*
Thiothrix†‡			0.5*-1.0
Fungus:			
Achlya			0.6*
Leptomitus	0.40	3.3	
Saprolegnia†	0.18	1.5	
Miscellaneous:			
Chara†	0.10 –0.50	0.8-4.2	
Nitella flexilis† ..... Objectionable	0.10 -0.18*	0.8-1.5	
Potamogeton†	0.30 -0.80	2.5-6.7	
Nais†			1.0*
Blood worm, chironomus†			15.0-50.0
Blood worm, gnats			3.0

The organisms where odors are expressed have been in sufficient quantity at one time or another to cause the characteristic odor.

[1]The quality of water (hard or soft) and temperature has a decided influence on the requisite copper dosage. The harder the water, and the colder, the higher the dosage required. To under-treat is a waste of chemical and further—the whole dosage must be applied at one operation.

*Dosage successful in New York City's supplies.

†These organisms have caused trouble other than odor.

‡These organisms have been affected by chlorine producing characteristic odor and in many cases controlled by dosage ranging from 0.3 to 3 ppm., depending largely on amount of organisms.

§Controlled by excess caustic lime, 5 ppm., in the case of diatoms (48 hrs.).

(*These data have been taken from the very useful booklet—"The Use of Copper Sulphate in the Control of Microscopic Organisms"—prepared by Dr. Hale for Nichols Copper Company, New York City.)

Los Angeles' Improved Dry-Feed Coppering Machines Used in Algate Control, Surface Application Have Proved More Economical and Effective. All Shallow Areas Are Reached Easily

TASTE AND ODOR CONTROL PRACTICES

By F. E. STUART, President

Activated Alum Corporation, Baltimore, Md.

Taste and odor control is now second only to the production of a safe water. The cost has been studied carefully and has been weighed against its importance as a routine treatment.

Now that the economics of taste and odor control by applying large dosages of powdered activated carbon have been compared with the economics of closely controlled coagulation, involving carbon adsorption, a new flow scheme is becoming apparent. A combination of these two methods of treatment appears to be the most overall efficient and economical.

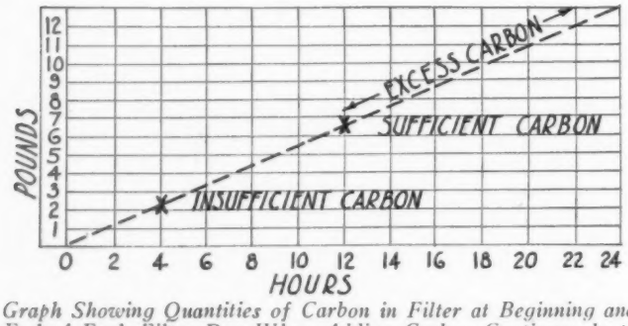
A short review is necessary to bring up to date the work that has been done on carbon by observers in the field. Further, to point out why this new type taste and odor control flow scheme is the most practical.

When alum is added to water and coagulation is produced, a large percentage of taste producing elements in the raw-water is precipitated in the settling basins. This is common practice and the effectiveness coagulation is taken for granted.

Previous to the introduction of activated carbon, these precipitated impurities underwent decay and generated gases and liquids of decomposition, which contaminated the newly coagulated water passing through the basins. Putrefying and liquefying sludge in the settling basins is a more common cause of tastes and odors than generally realized. A high chlorine demand in the filtered water and of tastes in dead ends are created by the same phenomena. This is not difficult to appreciate when one remembers how badly the basins smelled when they were last cleaned.

Carbon in the Coagulation Stage

At Daytona Beach, Fla., Superintendent Tippins in 1931 found that carbon used in the coagulation process would inhibit bacterial activity in the settled sludge—resulting in odorless sludge and odorless filtered water. These findings were later confirmed by Furman at Toledo, Ohio, and Fitzgerald at Norfolk,



Graph Showing Quantities of Carbon in Filter at Beginning and End of Each Filter Run When Adding Carbon Continuously to the Applied Water. (Based on Dosage of 12 lbs./MG. and Filter Runs Averaging 24 Hrs.)

Va. This effect of carbon on coagulated sludge has become known as "Stabilization of Sludge."

Because of the good results obtained, other observers added carbon to the mixing chamber in dosages sufficient to remove the tastes and odors present,—dosages between 18 and 32 pounds per million being the most common.

Middlestadt in Sacramento, Cal., about this same time made a careful study of the amount of carbon needed to stabilize sludge and found this dosage to be very small—from 2 to 4 pounds per million gallons. In a recent survey 54 per cent of the plants now using carbon for taste and odor control have been adding small dosages of carbon to the mixing chamber to stabilize sludge and condition the filter sand.

Split Dosage

Later work showed a further reduction in the cost of carbon treatment by utilizing a split treatment; adding half of the total carbon dosage to the mixing chamber and half to the water flowing to the filters. More complete taste control has been accomplished thereby.

Comparing the results between large dosages of carbon added continuously to the water flowing to the filters, large dosages added to the mixing chamber and split treatment the last proved to be the most economical. This brought about the latest change in treatment practice—adding the total amount of carbon to each filter after washing (about 4 to 6 pounds per million gallon filter area) and the addition of sufficient carbon to stabilize sludge and condition the filter sand, along with the alum dosage. A convenient method of doing the latter is to utilize the ready prepared activated alum which contains the required quantity of powdered carbon.

The floc produced by activated alum is more easily controlled than ordinary alum, because of the millions of tiny activated carbon particles which assist in the formation of the floc. A stable sludge will result and stable filter sand also, because the carbon particles are distributed throughout the floc. The floc does not break down as easily as ordinary alum floc and it has been found that less residual alumina is present in filtered water when activated alum is used.

Filter Dosing

Individual observers, led by Smith at Richmond, Va., showed reason why carbon should be added in one "Shot" dosage to the filter *after* washing instead of adding carbon continuously to the water flowing to the filter.

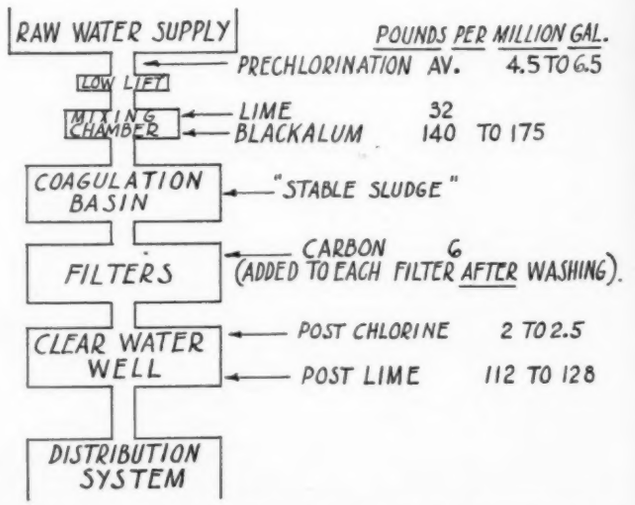
The common basic reasoning for such applications is that with carbon added continuously to the water flowing to the filters (we will say 12 pounds per million gallons), there is more carbon on the filter when it is taken out of service for washing than at any other time. Likewise, there is insufficient carbon on the filter for the first few hours of service, unless higher dosages than actually needed are applied. By estimating the amount of carbon actually needed for each run the dosage if added all at one time, produces a big saving in carbon. Average dosage of 4 to 6 pounds, per million gallons of filter area, seems to meet requirements between filter washings.

The following typical new type flow scheme for taste and odor control is used by Mills of the Southern Pines, N. C., Water Department:

Treatment	Pounds per Million Gals.		
Prechlorination	4.5	—	6.5
Lime, average	32		
Black-Alum (Activated Alum), average	140	—	175
Activated Carbon	6*		
Post Chlorine, average	2	—	2.5
Post Lime, average	112	—	128

*Carbon added to each filter following the wash.

This review points out why taste and odor control can be obtained more economically by means of good coagulation and car-



A Suggested and Tested Flow Scheme—That of Southern Pines, N. C.

THE HUDSON COAL COMPANY, SCRANTON, PA.

ANTHRAFILT

The Successor to Sand as a Filter Medium

PARTIAL LIST OF LOCALITIES USING ANTHRAFILT IN MUNICIPAL AND INDUSTRIAL FILTERS

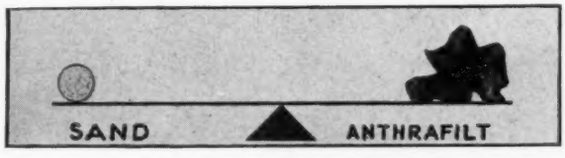
Little Falls, N. J.	New Toronto, Can.	Bethlehem, Pa.	Denver, Colo.
Indianapolis, Ind.	Glendenin, W. Va.	Baltimore, Md.	Alcoa, Tenn.
New Canaan, Conn.	Spartanburg, S. C.	Louisville, Ky.	Peoria, Ill.
Oklahoma City, Okla.	Greensboro, N. C.	Pittsburgh, Pa.	Raton, N. M.
Jacksonville, Fla.	St. Paul, Minn.	Cleveland, Ohio	Trenton, Mich.
Port Arthur, Texas	Iowa City, Iowa	Corondelet, Mo.	Roanoke, Va.
Grand Canyon, Ariz.	Leominster, Mass.	Richmond, Cal.	Buffalo, N. Y.
Philadelphia, Pa.	Kansas City, Kan.	Baton Rouge, La.	Madison, Wis.

WHAT IS ANTHRAFILT?

Anthrafilt is made from SELECTED Pennsylvania Anthracite which has been cleaned, screened, and hydraulicly classified to yield sizes suitable for filter purposes. It is successfully used as a mechanical aggregate in place of sand and gravel in all kinds of filters—i.e., rapid filters, slow filters, household filters, pressure filters, mechanical sewage filters, and sewage sludge-beds.

FILTRATION RATE OF ANTHRAFILT FAR GREATER THAN THAT OF SAND

Experience shows that the filtration rate of 125 m.g.a.d. cannot be greatly exceeded with sand if a satisfactory effluent is to be obtained. With Anthrafilt this rate is almost doubted. The use of Anthrafilt has saved thousands of dollars for users that would otherwise have been required to increase filter plants to the required capacity.



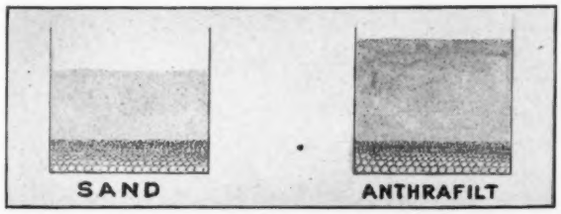
The bulk of a given weight of sand and Anthrafilt is shown above. The angularity results in less packing and higher filter rates.

ANTHRAFILT GIVES LONGER FILTER RUNS

Due to the vast difference in shape of the angular grains of Anthrafilt and the fact that they differ from each other in specific gravity, this filter medium does not classify to the degree that sand does after backwashing. This means that THE WHOLE DEPTH OF BED AND NOT MERELY THE UPPER SIX INCHES TAKES PART IN THE FILTER OPERATION.

Since larger sizes than sand can be used without sacrificing the quality of the finished water, there is LESS CLOGGING WITH ALGAE OR OTHER FIBROUS SUBSTANCES, LESS CRACKING AND PULLING AWAY FROM SIDE WALLS.

Moreover, Anthrafilt with greater surface has greater entrapping ability than sand in removal of turbidity and bacteria. All these factors contribute to longer filter runs and result in a saving of at least HALF THE WASH WATER REQUIRED for sand. This also means that the TIME OUT OF SERVICE IS CUT IN HALF.



Clean filters are obtained because a fifty per cent expansion is obtained with half the backwash required for sand of the same size.

ANTHRAFILT DOES NOT COAT WITH LIME

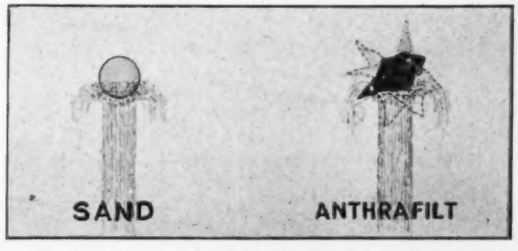
Coatings of all kinds do not build up as fast on Anthrafilt as they do on sand, nor do they adhere as tenaciously to the carbon surface. This is especially true of lime which flakes off easily and does not cement grain to grain as it does in the case of sand. Sand is acid and reacts with Alkaline waters, whereas Anthrafilt is chemically neutral and does not react with alkaline or acid waters.

IRON AND MANGANESE SALTS WASH OFF

Iron and manganese salts are precipitated on Anthrafilt in the form of a dark brown slime when applied water is treated with lime and coagulated in the normal manner. This slime is almost entirely removed during backwashing, leaving just sufficient coating to act as an effective catalyst for further removal of iron and manganese.

ANTHRAFILT OVERCOMES RIDGING AND MOUNDING

The ridging and mounding of gravel beds may be due to many causes, such as leaves or other large foreign particles coming to rest on the top of the gravel, cementation of gravel areas, deep mud patches, faulty underdrains, improper grading of gravel, etc. If the cause is not due to major causes, mounding may be overcome by using Anthrafilt because it may be more uniformly agitated and more easily cleaned than sand.



Upward impulse of water produces greater agitation of angular grains, hence Anthrafilt beds are cleaned more effectively.

ANTHRAFILT COSTS LESS THAN SAND

Based on the delivered price per cubic yard, Anthrafilt costs less than sand. There are ¾ cubic yards of sand in a ton, while a ton of Anthrafilt occupies over 1¼ cubic yards. If 100 tons of sand are necessary for a job, only 53 tons of Anthrafilt are required. The exceptionally light weight of Anthrafilt also gives it an advantage over sand in freight cost.

SUMMARY

a. First cost is usually lower than sand.
b. A high degree of expansion is obtainable.
c. Coarse sizes can be used.
d. Longer filter runs are possible.
e. Higher filter rates are possible.
f. Wash water costs are reduced.
g. No cementing with lime, manganese or iron.
h. Gravel beds stay flat.

Samples, Quotations and References will Be Gladly Furnished Without Obligation

bon added to each filter immediately after washing—than high dosages of carbon at any one point in the treatment.

Carbon is now regarded as a routine treatment—to improve coagulation and remove tastes.

Carbon in the pretreatment through activated alum and the addition of 4 to 6 pounds of carbon per million gallon of filter capacity (added all at one time to the filter after washing) is now considered the most efficient and economical method. (See flow scheme).

For serious taste and odor epidemics which are only temporary, large dosages of carbon are necessary and should be applied as a split treatment.

Ammoniation

Suggested by Enslow and probably first introduced by Jordan at Indianapolis, Indiana, later adapted in many plants including Easton, Pa.; Trenton, N. J., and Fort Pierce, Fla., etc., the trend in ammonia application during the past year has been in connection with its use after filtration; it being added after the post-chlorine dosage.

This seems to be the most economical method of application because the dosage of ammonia used is that to combine with only the existing free chlorine.

Users of ammonia continue to favor anhydrous ammonia in cylinders because of ease of application and accuracy of control.

It is well known that ammonia, unless used in the proper concentration in the pretreatment, will in many instances increase algae growths along the sides of the settling basins. This increase in algae growth is controlled, however, if high dosages of ammonia and chlorine are used. These high dosages are uneconomical, and, therefore, prechlorination alone is generally adopted as the most economical practice; adding the ammonia after filtration.

Chlorination

The benefits of such a versatile product as chlorine cannot be outlined in more than a general way. Chlorine in the pretreatment is becoming more generally used, because prechlorination has several advantages in routine plant operation. All plants should have duplicate chlorinators for post-treatment and provisions for prechlorination.

Experiences of the writer have been that high residuals in prechlorination are not advisable at any time. High prechlorination residuals hinder taste and odor control.

High prechlorination residuals are not necessary to improve coagulation or lengthen filter runs. Experiences of Fitzgerald at Norfolk, Va., show that the typical "water flea" can be stunned with prechlorination, without a residual reaching the filters. Prechlorination at the rate of 8 pounds per million gallons was just as effective as 30 pounds. The chlorination did not "kill," but "stunned" them to such an extent that the alum floc would precipitate them and then the filter runs lengthened out.

Many other experiences with chlorine in the pretreatment confirm the writer's opinion that it is a most useful tool to improve general plant operation, but should not be used in concentrations to produce high residuals in applied water. Especially is this true when dealing with algae tastes.

Acknowledgment: This article has been drawn largely from a paper read by the author before the Kentucky-Tennessee Section of A.W.W.A., March, 1936.

Inclined Diagonal Pipe Runs—Calculating Pipe Lengths

By CHARLES FRICK

Darby, Pa.

Water works men may find the following formulas interesting and helpful in figuring lengths of pipe and tie rods on inclined diagonal runs.

The formulas are also useful in finding the approximate angle of fitting, theta (θ), required (when bell and spigot pipe and fittings are used) when the dimensions in three planes have been decided upon.

The evolution of the formulas (see illustration) are also given in case the principle of revolution to a vertical plane may have further advantages in similar problems.

The subtraction of the center to end of spigot and center to back of bell taken from D gives the true length of pipe required.

Sketch Explanatory of Formulas for Lengths of Pipe for Diagonal Runs and Angle of Fittings

A.—When measurements in three planes are known, then

$$D = \sqrt{A^2 + B^2 + C^2} \qquad \text{Formula I}$$

$$L\ (\theta)^{-\tan} = \frac{\sqrt{A^2 + B^2}}{C} \qquad \text{Formula II}$$

Example: Let A = 5′6″, B = 3′0″, C = 14′9″
Find (θ) and length of pipe required on 8″ line.

$$D = \sqrt{(5.5)^2 + (3)^2 + (14.75)^2}$$
$$= \sqrt{30.25 + 9 + 217.56} = 16.025' \text{ say } 16'0''$$

$$L\ (\theta)^{-\tan} = \frac{\sqrt{(5.5)^2 + (3)^2}}{14.75} = \frac{\sqrt{30.25 + 9}}{14.75}$$
$$= \frac{\sqrt{39.25}}{14.75} = \frac{6.265}{14.75} = 0.42474$$

$L\ (\theta) = 23° +$ and a one-sixteenth curve may be used.
Length of pipe = D — (C to E of S. + C to B of B.)
= 16′0″ — (2′1″+) = 13′11″—

B.—When measurements in two planes are known and angle of fitting (θ) decided upon, then

$$D = \sqrt{A^2 + B^2} \times \text{Csc}\ (\theta) \qquad \text{Formula III}$$

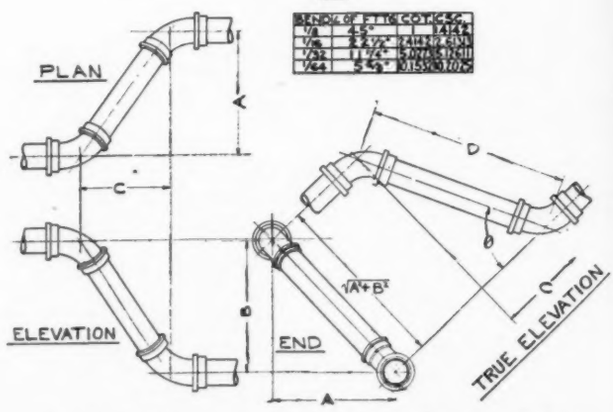
$$C = \sqrt{A^2 + B^2} \times \text{Cot}\ (\theta) \qquad \text{Formula IV}$$

Example: Let A = 8′0″, B = 9′6″, (θ) = 45°
Find—C and length of pipe required on 12″ line.

$$D = \sqrt{(8)^2 + (9.5)^2} \times \text{Csc } 45°$$
$$= \sqrt{64 + 90.25} \times 1.4142$$
$$= 17.56' = 17'6\tfrac{3}{4}''$$

Length of pipe = D — (C to E of S. + C to B of B.)
= 17′6¾″ — (2′1⅞″) = 15′4⅞″

$$C = \sqrt{(8)^2 + (9.5)^2} \times \text{Cot } 45°$$
$$= \sqrt{64} = 90.25 \times 1$$
$$= 12.42 \times 1 = 12.42' = 12'5''$$



Sketch Explanatory of Formulas for Lengths of Pipe for Diagonal Runs and Angle of Fittings

HELLIGE, INC.

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PRODUCTS: Apparatus and Equipment for the Analysis of Water, Sewage, and Industrial Wastes

HELLIGE POCKET COMPARATOR

(Size of complete apparatus ready for use, only 3¾ x 3¾ x 1½".)

HELLIGE GLASS ELECTRODE pH-METER

A moderately priced instrument for the electrometric measurement of the degree of acidity or alkalinity. Reads directly in pH units over the complete range of 0 to 14 pH. Extremely simple to use. **The ideal apparatus for pH tests of water and sewage.**

HELLIGE TURBIDIMETER

With this instrument, it is not necessary to prepare and use standard suspensions. It is easy to operate, produces results of highest accuracy, and reads all turbidities down to zero.

Hellige comparators are equipped with solid glass color standards which are available for more than 30 pH indicators, chlorine determination, and all popular water tests. These standards are non-fading, and therefore permanently reliable. They are the only standards which carry a guarantee of accuracy not merely for one or five years, but FOR A LIFETIME. They are economical: bought once, they serve for practically an unlimited length of time. They are the lightest in weight and easiest to manipulate.

The durability of the comparator housings has been greatly increased by making them of Textolite, a corrosion resistant molded plastic, manufactured and molded by General Electric Company.

Write for bulletins containing detailed information.

We also supply inexpensive potentiometers, bacteria counting apparatus, Hellige all-glass Sedgwick-Rafter counting cells and accessories, micrometer discs, indicators, and reagents.

METERING: PRACTICAL METHODS OF PROCEDURE*

By E. H. RUEHL†

"To meter or not to meter?" That is the question.

Those who have gone through the problem of making initial installation of water meters know what significance these few words can have and what discussions can be caused thereby.

However, metered water service is being acknowledged more and more as being the best all-round method of distributing the indispensable commodity, water. This is especially true since the unprecedented drought of 1930, and I am sure that if more communities were metered at that time the effects of the drought would have been less severe due to the lessened wastage of water.

Why Services Should Be Metered

There are many good reasons why water services should be metered, a few of which are:

1. It is the fairest way of selling water, as all customers pay in proportion to their respective consumptions.

2. The water department or company has a pretty good check on the amount of water sold and by comparison with readings of a master meter can better establish losses and leakage and thereby reduce waste in the system in general.

3. Leaks in consumers' service lines can better be located.

4. Knowledge of the various water consumptions is essential in establishing equitable water rates, and the only way in which this information can be obtained and analyzed is by metering of all services.

In some cases, especially in the municipally owned plants, there are certain institutions, such as schools, hospitals and the like, that are supplied with water without charge, and these should be metered and read regularly to get the full benefits of 100 per cent metering.

And here let me digress a little to state that the words municipally owned are generally a misnomer, as in the majority of cases the municipality has a large obligation in the form of outstanding bonds, and the only part that is really municipally owned is the amount covered by bonds purchased back, or some such similar item. This is mentioned here because in the municipally operated plants we are so often confronted with the statement that the people own the plant and for this reason they should have all the water wanted for some flat rate that is nowhere commensurate with the cost of producing the water, the fixed charges being lost sight of entirely.)

5. It has been proven that as meters are installed that consumers' wastes have been reduced and this in turn effects economies in the amount of power required to pump, if it be a pumping plant, and in treatment costs, which are getting higher and higher every day.

6. As the water requirements of the city are kept within bounds and more or less controlled. the size of the treating and pumping plants and storage and distribution systems are kept to a minimum, thereby keeping capital investment to a minimum, as well as the necessary interest and sinking fund charges, which all result in keeping of the water rates at the lowest possible figure.

7. As the time will most likely come when sewage treatment will become necessary in a good many places, the lowering of the water losses and wastes will redound to the town's advantage in requiring a plant of smaller capacity than would be necessary if water usage and wastage were uncontrolled. Likewise, sewage pumping costs will be less.

With all these reasons in favor of metering, the only ones against it are generally found to be caused by the selfish motives wherein certain customers may want to use unlimited quantities of water without paying a just price therefor. This can be overcome in a great many cases by explanation, and, in spite of the fact that many may be adamant at first, good results are usually obtained.

Another argument against metering is sometimes set forth in that it is claimed that sanitary conditions will not be maintained if water usage be curtailed due to the installation of meters, but it has been shown that for all purposes about 25 gallons per capita per day is all that is absolutely necessary. Under any ordinary rate the cost for this requirement for the average family for an entire month would be modest, in most cases less than the cost of one filling of the gasoline tank of the automobile.

It can therefore be seen that metering is beneficial to both the municipal plant or privately owned company as well as to the consumer, since it contributes a means of compiling equitable rates and keeping bills to a minimum.

Ownership and Location of Meters

Since the type of meter and location of meter setting is governed to some extent by geographical location and local conditions, the remarks that are to follow must of necessity be confined more or less to a particular section and will apply to Virginia.

The ownership and location of the water meter are two subjects on which divergence of opinion exists. In the writer's opinion, the meter should be owned by the water department or company (being charged to capital account) and all maintenance should be done by the owners and charged to operating costs. In Virginia the meter setting just inside the curb line offers so many advantages over other locations that these readily outweigh any disadvantage in the nature of a small additional installation cost, should this be the case. In a good many houses in this section of the country there are no basements in which to locate a meter.

Advantages of Outside Setting

The advantages of such outside setting, located in the sidewalk space, are in general as follows:

1. Meter reading is greatly facilitated due to the fact that the reader never needs to wait for a response from the householder on knocking, and should the party be absent it would necessitate making another trip to get the meter reading if the meter were located inside the house. The distance the meter readers have to walk is lessened when outside settings are used, and this in turn permits more meters to be read per day.

2. The meter is always accessible to water department employees for reading, inspecting, testing and repairing.

3. The danger of the meter readers and other water department employees from attacks from vicious dogs is eliminated.

4. The chance of unauthorized persons entering the house in the guise of water works employees is greatly eliminated.

5. Chance of the meter being covered by rubbish, coal, kindling wood. etc., is done away with when the outside setting is used.

6. More accurate readings can be procured when outside settings are used because of better lighting outside than generally exists in basements, under porches or other places where meters might be set.

7. The line of separation between the water department and property owners' liability is clearly defined and there is not much chance of unauthorized connections being made behind the meter.

8. In case of necessity of cutting off the water for non-payment of bills there can be no dispute as to entering the premises if the meter and control are located at the curb line.

9. The outside setting should be in a locked box and, as it is below the ground, is not so apt to be tampered with as would a setting in a more conspicuous place not protected by a box.

10. Less danger of damage to the meter by hot water exists if set at the curb.

11. Danger from freezing is practically eliminated in a well set meter, and in case of fire in the building supplied the meter is not in danger of being destroyed.

In view of all these reasons the writer is of the opinion that the entire meter setting, including the necessary cut-off valve, should be located in the sidewalk space behind the curb line, and that the water department's or company's maintenance and obligations should stop at the customers' side of the meter.

Type of Setting

The following remarks apply to the smaller size meter up to 1-inch, and when larger sizes than this are used the condition must be studied separately and settings made to suit.

It is realized that a properly set meter, although not always the cheapest, will receive more attention in general from the water works operatives and in turn pay higher returns to the department.

It is a good plan to set the meter in a yoke with at least a control valve at the inlet side, although some prefer valves at

*From WATER WORKS AND SEWERAGE.

†Field consultant, Virginia League of Municipalities.

FILTRATION EQUIPMENT CORPORATION

Sales Office: 10 East 40th Street, New York, N. Y.

PRODUCTS: THE AUTOMATIC MAGNETITE FILTER — CONKEY ROTARY VACUUM FILTER

THE AUTOMATIC MAGNETITE FILTER:

The magnetite filter is an automatic mechanical cleaner strainer for effective removal of suspended solids from primary and secondary settled sewage effluents at reasonable cost.

Magnetite Filters in Operation, Denver, Colo.

The filter medium consists of a three-inch depth of magnetite iron ore screened to size and supported on a non-corrosive screen. A solenoid alternately magnetized and demagnetized washes the fine solids caught between the particles of ore by lifting and dropping a narrow strip of the filter layer. Wash water containing the impurities passes over into a separate compartment and is pumped back for re-treatment or other disposal.

DESIGN FEATURES:

Magnetite filters are now being designed for: (a) Upward or downward flow as an integral part of circular or rectangular primary or secondary settling tanks; (b) for installation in separate structures following primary or secondary sedimentation. The separate structures may be either circular or rectangular in shape. Fine or coarse grained magnetite may be used, depending on local requirements.

INSTALLATIONS:

The present automatic magnetite filter is the result of eight years' development and full scale operation. Magnetite filter installations are now in operation to treat a total maximum effluent flow of over 400 m.g.d.

APPLICATION:

In Plain Sedimentation:—Magnetite filters reduce settling capacity and improve the effluent by 40%. Settling for 1.5 hours plus magnetite filtering removes 70 to 75% of the suspended solids from raw sewage. Chlorine demand is 15 to 25% less for filtered than for unfiltered effluents.

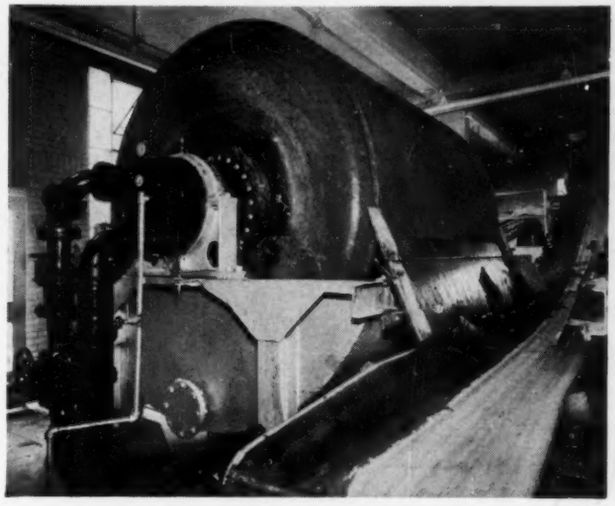
Chemical Treatment:—Magnetite filters reduce coagulation and settling time, save 50% of the chemicals required and improve the quality of effluent.

Activated Sludge:—Magnetite Filters reduce size of settling tanks, improve the effluent or save aeration tanks and power for compressing air. They act as a safeguard against irregularities in operation and as a polish on the final effluent.

Trickling Filters:—By installing a magnetite filter on preliminary settling tanks, it reduces their size and also reduces the physical suspended solids load applied to the trickling filters. On final humus tanks it reduces their size, strains out solids which fail to settle and polishes the final effluent.

Filtering through Automatic Magnetite Filters results in uniform effluents irrespective of variation in character of influent and helps to eliminate problem of secondary sludge depositions in receiving bodies of water.

Putrescible solids are removed from the sewage effluents by the magnetite filter at lower costs per ton removal than by any other method in the same range of treatment.



Vacuum Filter at Elmira, N. Y.

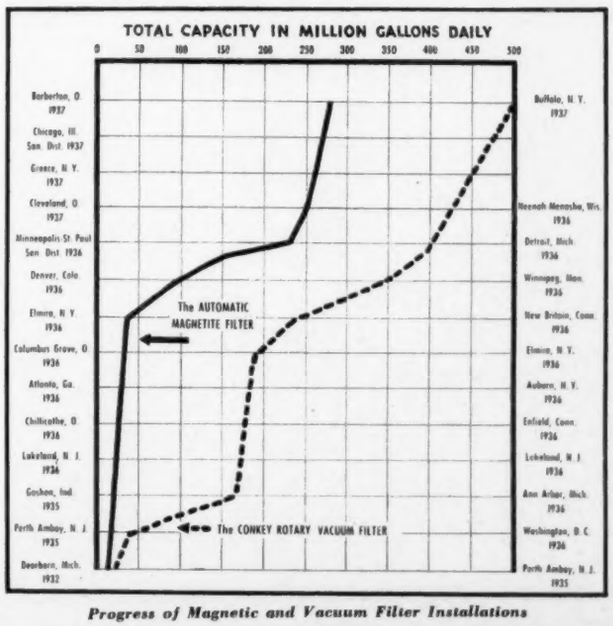
CONKEY ROTARY VACUUM FILTERS:

For dewatering of raw settled, chemically coagulated and activated sludges.

Built of the most improved design and best of materials for acid or alkaline conditions.

Produces cake of 8 lb. dry solids per sq. ft. per hour with 1.5% ferric chloride and 8% lime and a resultant moisture content of 65%.

Conkey vacuum filters now in operation or under construction at sewage plants treating a total maximum sewage flow of 800 m.g.d.



Progress of Magnetic and Vacuum Filter Installations

both the inlet and outlet sides. This does away with the customary curb stop and box.

The meter in its yoke, and with the control valve, should be set in an earthenware, concrete or iron box with sufficient clearance between the risers, if they be used, that the cold ground outside cannot cause the water in the pipes or meter to freeze. A type of box that has proven very satisfactory in our section of the country is one 18 inches in diameter and 24 inches deep, with side slots at the lower end to accommodate the varying depths of the service pipe. The latter, we feel, should be about 24 inches below the ground.

It is important that a lid be provided that fits the top of the box tightly, preferably being locked on with some kind of a locking device. If the lid is fastened on there will be no circulation of air in the box and consequently less danger from freezing. Another advantage is that if the lid is kept on tightly there is less danger of persons tampering with the meter or of pedestrians catching their feet in the hole, with a possible damage suit resulting.

It is also very important that the bottom of the box extend below the maximum frost line so that the warm air from below can rise up around the meter and risers and keep the atmosphere in the box above freezing. In extreme cases it has been found that a smaller tile pipe about 8 inches in diameter put vertically into the ground below the bottom of the regular box (to reach warmer levels) overcame freezing troubles by admitting warmth from below.

Meter Reading

In the writer's opinion, meters should be read monthly, if this is possible, as by so doing a closer touch is kept on losses and wastes, and due to the visiting of each meter every thirty days the stopped meter and other irregularities can be more effectively dealt with. In case a customer has a leak he can be notified within a reasonable time if the meters are read monthly, but if they are read, say, quarterly, the amount of leakage passed will more likely be an appreciable amount and cause some disagreeableness when an attempt is made to collect the bill.

Experiences at Bluefield, Virginia*

If you will pardon personal experiences, it may be of some interest to tell how the town of Bluefield recently attacked the problem of setting 700 meters at the rate of something like 100 per week. This was carried on as follows:

A work sketch was first made up and the various kinds of equipment decided on. After the meters, yokes, boxes and covers were ordered out, some figures were made up giving the length of pipe to be cut from the service to allow for elbows, yoke, valve, etc., and the vertical distance that cover, meter, yoke and fittings required was figured and each made into a constant.

Actual installation started with several men digging holes, located from the curb boxes wherever possible, in a certain well defined section so that one foreman could keep all things going. Two men, both of whom had some previous pipe fitting experience, were formed into a "gang" and given instructions how to set the meters, and they then worked together for about a day. These men then were given a helper each and two setting "gangs" were formed and these two helpers were in turn given helpers and four setting "gangs" were formed in a few days. The work was carried through, with as many men as were necessary to prepare the holes ahead of them.

Tools Required

Each of these setting gangs of two men each was furnished with a ratchet die holder and one-half and three-quarter inch dies, a hack saw, two 10-inch Stillson wrenches, a pipe vise attached to a four-legged board, a home-made wooden straightedge, and a pair of hip boots. The men provided their own rules. The meters, yokes, boxes, covers, pipe, etc., were supplied to the location by a Ford truck. Galvanized nipples of various lengths were purchased and used wherever possible, as they could be purchased cheaper than we could buy, cut and thread the pipe.

When the hole was opened down to the service pipe the meter-setting gang (two men) came along and the first thing they did was to lay the straight-edge across the hole and measure down to the service pipe, and from this the proper "constant," referred to above, was subtracted, which gave the length of risers necessary to bring the top of the meter to the desired point below the meter box lid. If there was a standard nipple of length somewhere near this dimension it was used. If not, the helper would cut pipe to the proper length and thread it. The meter setter in the meanwhile would be cutting a piece of pipe predetermined length out of the service line and threading the cut ends for elbows. The risers were then screwed in and the yoke and meter set, after which the box was put in the hole. By using a set of specially made hooks the box was easily adjusted around the meters and risers, and the cover put on.

Two men constituted the back filling gang and followed up all setting gangs, backfilling all holes and seeing that the lids were properly fastened.

If the existing cut-off in the service line was so that it could be used to control the water it was used, but if not the meter setter would cut and thread the pipe under pressure, which only took a very few minutes. He would screw the riser pipe with control valve on, bail out the hole, and go on without having to dig back to the main or cut the water off of a section of the town. The water lost amounted to very little.

One foreman looked after the entire job and 700 meters were set at the rate of about 100 per week.

The cost of this work complete, including tools, boots, and everything, was slightly under $19 per setting, which also included the changing of some services where it was necessary.

We believe that in a place where the services are fairly close together one foreman could handle about six meter setting gangs with the necessary hole diggers and could set about 150 meters per week, providing that everything is thoroughly planned ahead.

*When this article was written the author was City Manager of Bluefield, Va.—Ed.

Meter Repair Practices*

Water meter castings are painted by spray gun equipment. The meter casting sets on a turntable which revolves slowly. The colors used are Bronze and Aluminum.

Air chambers have been installed on the influent side of all the meter testing machines. This eliminates water hammer caused by the quick opening and shutting valves, especially effective when testing large size meters.

The use of Monel metal baskets for dipping meter parts in Dearborn 134 solution has been much more economical than the use of cheaper baskets.

An electric drill held in place by a suitable clamp arrangement is used for cleaning meter parts. The drill is substituted for a rotary wire brush. This cleans meter parts in a hurry.

The uses of compressed air in a meter repair shop are many. This added convenience in meter shop repair work will speak for itself.

The use of a hand press similar to the press used on electric drills is a sure way of observing the fit of the disc in the chamber before the meter is put together. This eliminates the guess work connected with tight or ill-fitting discs.

An elevated container of gear lubricant is directly connected to a quick opening valve with string attachment. This gives positive control of the amount of lubricant added to the gear train chamber because it closes so quickly—thus eliminating the mess which generally accompanies the handling of gear lubricant.

*Courtesy, E. T. Cranch, Mgr., New Rochelle (N. Y.) Water Co.

OLIVER UNITED FILTERS INC.

33 West 42nd St.
New York, N. Y.

221 N. La Salle St.
Chicago, Ill.

351 California St.
San Francisco, Calif.

Factories: Oakland, Calif., Hazleton, Pa.

PRODUCTS

Oliver Continuous Mechanical Sludge Dewaterer.
Olivite Acid Pump.

EXPERIENCE

Wide experience, broad understanding of sewage treatment methods and sound engineering, combined with extensive research, are requirements of the utmost importance for the successful dewatering of sewage sludges by vacuum filters. Different localities produce sludges with widely varying dewatering conditions and only experience can insure a satisfactory and economical dewatering installation.

The Sanitary Department of Oliver United Filters has concentrated its attention upon the successful dewatering of sewage sludges for seventeen years. Research by its own staff and in conjunction with Sanitary Engineering organizations has broadened the scope of sludge dewatering and improved its economies.

A number of prominent cities, widely separated geographically, are using Oliver units. The experience gained thru these successful installations is available to any city planning modernization of its sludge dewatering methods. Well over half of the Oliver installations to date are for cities having less than 10 mgd flow.

HANDLING OF INDUSTRIAL WASTES

Removal of industrial wastes in stream pollution control is receiving considerable attention at this time. In a recent project an Oliver is to dewater a combined tannery waste with domestic sewage. Some water treatment sludges may be disposed of in the same efficient manner.

ADVANTAGES OF CONTINUOUS MECHANICAL DEWATERING

Compact and completely housed installation.
Flexibility of operation on varied types of sludges.
Sludge dewatering independent of weather conditions.
Sludge better prepared for incineration.
Elimination of unsightly sludge bed areas with their inherent odor and fly nuisance problems.

NEATNESS OF INSTALLATION AND ABSENCE OF NUISANCE FACTORS

No stronger evidence of these two important features of Oliver Mechanical Sludge Dewaterer can be found than in the Middletown, Conn., plant shown at the right. Note the office in the next room. No sludge dewatering system that was objectionable to the eye, ear or nose could be allowed so near to the office.

SLUDGES HANDLED

Waste Activated, Waste Activated and Raw Primary, Raw Primary, Imhoff, Separate Digested Primary, Separate Digested Mixed, Water Softening, Water Softening combined with Digested Primary, Industrial Wastes combined with Domestic Raw Primary.

OLIVER ALL-ASSEMBLED SLUDGE DEWATERER

This unit, illustrated opposite, is ideal for small cities and large towns with flow rates of 1 to 2 mgd. It is shipped and installed all-assembled, making it a miniature mechanical dewatering plant. Only power, sludge feed and disposal and filtrate and water connections need to be made.

THE OLIVITE ACID PUMP

Ideal for pumping Ferric Chloride, Ferrous Sulphate, Alum and other corrosive solutions. Widely used in the process industries for acid pumping.

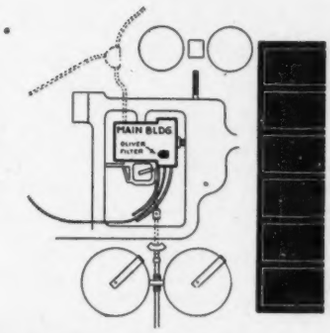
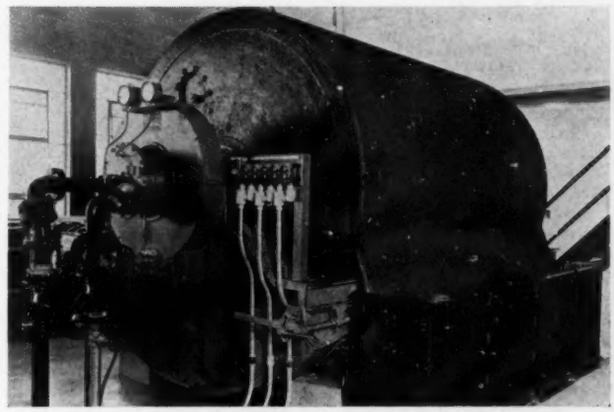
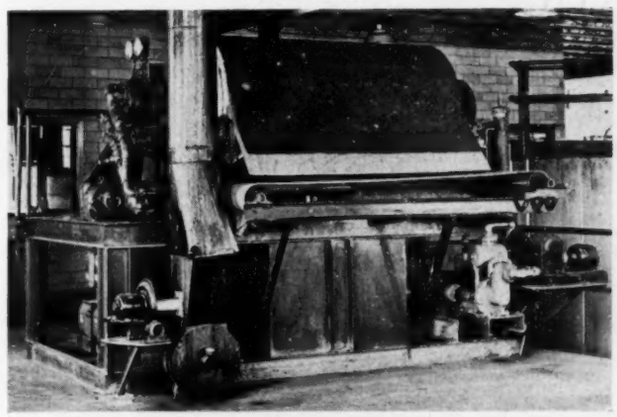


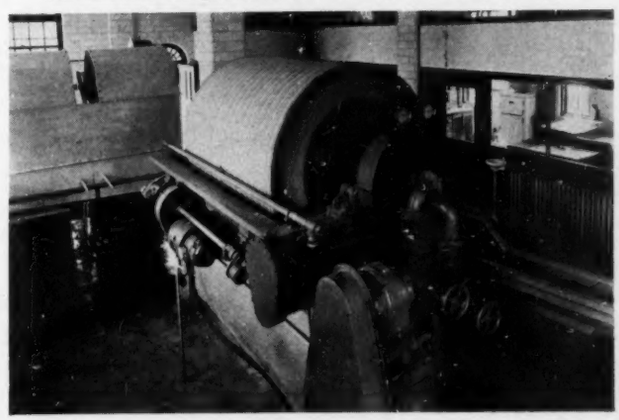
Diagram of actual Oliver Mechanical Sludge Dewatering installation. The large black area indicates how much drying bed space would be needed if the continuous mechanical dewaterer had not been selected. Note the compactness of the Oliver installation.



Standard Oliver Sludge Dewaterer at Springfield, Ohio. Note character of filter cake.



All-assembled Sludge Dewaterer at St. Charles, Ill. (see text).



Standard Oliver unit at Middletown, Conn. Note office in next room.

WATER METER TESTING PRINCIPLE AND PRACTICE

[*From "Testing Water Meters—Why and How"*]*

The testing of a water meter is very simple. It consists of checking the registration of the meter against the actual volume of water passing through the meter, as measured in an accurate volumetric tank or weighed on accurate scales.

Meter accuracy may be defined as the quotient obtained by dividing the meter reading by the actual volume of water. Thus a meter registering 9 gallons when 10 gallons are run through it has an accuracy of 9/10 or 90%. A meter registering 52 cubic feet on an actual volume of 50 cubic feet is 52/50, or 104% accurate.

Meter accuracy is commonly expressed in percentage fast or slow. Thus a meter which records 95 gallons when 100 gallons are run through it under-registers or is slow by 5%. A meter registering 102 gallons on the same volume would be 2% fast.

Good Practice in Testing

Before starting a test, water should be run through the meter or meters at a high rate, say 10 or 15 gallons per minute, until all the air is out of the meters and the line, and the delivery pipe to the tank is as full or as empty as it will be at the end of the test. Start the test flow with the test hand of the meter or meters on an even starting position or line on the dial. This can be done either by running water from the outlet of each meter until it has the test hand at the proper position, or the register can be turned around in the case until the test hand stands on the line.

When testing one meter at a time with calibrated tank or with scales having percentage beams, the test flow should be stopped when the meter has indicated the passage of the test amount. The percentage fast or slow of the meter can then be read direct from the tank gauge or from the percentage beam of the scales.

When testing several meters in series or when using scales or tanks without percentage markings, the flow should be stopped when the test volume of water has been run into the tank. The percentage fast or slow of the meter or meters can then be computed by dividing the meter readings by the actual amount of water. It will be seen that the computation will be much simplified if the amount of water is one, ten or one hundred gallons or cubic feet. Thus the divisor is one, which makes the meter reading direct in percentage of accuracy. Example: 100 gallons run through the meter; meter reading 96 gallons; meter accuracy 96%, or the meter is 4% slow.

Amount of Water for Tests

All test amounts except on lowest flow or "sensitive" tests should be at least enough to correspond to one complete revolution of the test hand on the meter dial. Often the test hand pinion is not in the center of the circle on the dial and this would introduce an error in reading with partial turns of the test hand. Common practice is to test on the small flows with an amount representing one revolution and on large flows with an amount representing ten revolutions of the test hand. On the other hand, it is possible to get an accurate test on a ⅝ inch meter with ten gallons or one cubic foot and many meter shops do not go beyond this. Of course the greater the amount of water the smaller would be the errors introduced by inaccuracies in readings.

Single or Series Testing

Meters can be tested one at a time or in series. When there are many meters to test there is a worth-while saving in water and time if several meters are tested at once. The number of meters in series or the number of units in the testing machine justified for any condition depend on the number of meters in the system and the frequency of testing. Testing machines or benches for up to 12 meters are in common use.

In series testing the flow can be stopped when the correct amount of water has been run through the meters into the tank, and the accuracy of each meter computed as indicated above. When only a few meters are tested in series it is possible to take advantage of the percentage calibration on the tank or scales by turning off the water when the fastest meter shows a registration of the test amount, reading the percentage accuracy of the meter, starting the flow again and stopping for each meter as it comes up to the desired reading. This method of obtaining the meter accuracy is not considered good practice as it involves changing the rate of flow for every start and stop involved.

Testing with Test Meters

For testing in the field the so-called test meter is convenient and satisfactory if only a rough check is desired. However, a test meter is only a meter and subject to the same variation in accuracy which is characteristic of all disc meters.

Further, a test meter is not positive in the same way as a tank or scales. Testing one meter with a test meter or with any other meter is simply comparing meters and is not recognized in many states which have regulations or laws applying to means or equipment for water meter testing. Field testing can be done much better and more accurately by means of a calibrated testing tank.

Money Value of Meter Accuracy

The accuracy of a water meter is a matter of dollars and cents to the customer and the utility.

Fortunately for the customers, water meters which were originally accurate cannot over-register beyond a slight speeding up in some water conditions. This action is self-limiting, for friction increases with the building up of the disc or piston and tends to counteract the speeding up. Water meters always slow down in service as they become worn, corroded or encrusted.

The intervals at which it is profitable to the water works to test meters and repair them depends entirely on the effects of the water and service conditions in making the meters under-register, on the value of the water taken but not registered, and on the cost of making the necessary tests and repairs. In other words, if the increased revenue from the meter pays a good return on the cost of making the meter accurate, it is simply *good business.*

Several states have recently adopted regulations which specify limits between meter tests in water utilities, both in time and

*A booklet distributed by Ford Meter Box Co., Wabash, Ind.

MFGR. NO. _____ CO. NO. _____ MAKE _____ SIZE _____

DATE PURCHASED _____ STYLE _____

INSTALLATION RECORD								TEST AND REPAIR RECORD									
INSTALLED		NAME	ADDRESS	Tap No.	Reasons for Removal	Removed		Date	Rate of Test			Repairs		Total Amt. of Water Passed Before Test	Tested By	REMARKS
Date	Reading					Date	Reading		Min. Flow	Inter. Flow	Max. Flow	Before Test	After Test			

Heading for a Suggested Form for Meter Record Card. This Can Be Adapted to Meet the Requirements of Any Meter Shop. Actual Size of Card Is 8½ by 11 inches.

in volume of water. These limits are necessarily broad, as the composition of water and its effect on meters varies widely in any state, and many utilities profitably test and repair more frequently than required. These regulations show the growing realization that meter testing *is* important.

The following table shows the value of water unregistered by meters of various percentages of slowness, with various amounts of water drawn through the meter and with water valued at from 10c to 50c per thousand gallons. These figures can be easily transposed into cubic ft. by recalling that 100 cubic ft. equals 750 gallons.

From the table it will be seen that with water at 10c per thousand gallons the return on the investment of testing and repairing a meter 4% slow will be only 40c with every 100,000 gallons of water drawn through the meter. It would take a large and active service to make frequent testing pay under these conditions.

On the other hand, with water at 50c per thousand gallons a meter failing to register 20% of the water passing through it (not terribly rare) would lose $1.00 for the water works with every 10,000 gallons. With these conditions maintained accuracy will pay a handsome return on the investment.

TABLE SHOWING VALUE OF WATER NOT REGISTERED BY METERS OF VARYING PERCENTAGES OF UNDER-REGISTRATION, WITH WATER FROM 10c TO 50c PER THOUSAND GALLONS, AND WITH THREE AMOUNTS OF TOTAL DRAFT.

	Value of Water Per 1,000 Gallons								
	@ 10c			@ 30c			@ 50c		
	Total Volume Drawn—Gallons x 1,000								
%*	10M	50M	100M	10M	50M	100M	10M	50M	100M
4	$ .04	$ .20	$ .40	$ .12	$ .60	$1.20	$ .20	$1.00	$2.00
6	.06	.30	.60	.18	.90	1.80	.30	1.50	3.00
8	.08	.40	.80	.24	1.20	2.40	.40	2.00	4.00
10	.10	.50	1.00	.30	1.50	3.00	.50	2.50	5.00
12	.12	.60	1.20	.36	1.80	3.60	.60	3.00	6.00
14	.14	.70	1.40	.42	2.10	4.20	.70	3.50	7.00
16	.16	.80	1.60	.48	2.40	4.80	.80	4.00	8.00
18	.18	.90	1.80	.54	2.70	5.40	.90	4.50	9.00
20	.20	1.00	2.00	.60	3.00	6.00	1.00	5.00	10.00

*Under-Registration Percent.

Steps in Testing a Water Meter

[A ⅝inch meter is used as an example. A larger meter would involve the same procedure but would require greater rates of flow.]

1. **Insert Meter in Tester**—Any means of connecting the meter water-tight in the test line is satisfactory but a regular tester is much more convenient.

2. **Flush Meter Out With a Large Flow**—This is to remove air from the meter and line. A flow of ten or more gallons per minute is desirable and should be continued until discharge indicates that all air is out of the line.

3. **Bring Test Hand of Meter to a Mark**—This can be done by stopping the water flow as the hand reaches the mark, or by turning the dial in the meter case if the meter bonnet is removed.

4. **Run a Test at 10 to 15 G.P.M. Running 50 Gallons or 10 Cu. Ft.**—It is desirable to run this much water although more would be just as good or better. Be sure the calibrated tank is empty or the scales balanced before the test flow is started.

5. **Run a Test at 1 to 2 G.P.M. Running 10 Gallons or 1 Cu. Ft.**—Here again the exact amount is subject to variation and more water can be run if there is plenty of time and water.

6. **Run ¼ G.P.M. Test, Running at Least 5 Gallons or ½ Cu. Ft.**—This low-flow test is important for reasons mentioned on pages 9 and 10.

7. **Make a Record of the Tests**—Put down in permanent form the accuracy of the meter at the three rates of flow, date of test and other pertinent information. See suggested record card on the reverse of this sheet.

IMPORTANCE OF TESTING DISC METERS AT THE CORRECT RATES OF FLOW*

By P. S. WILSON[1]

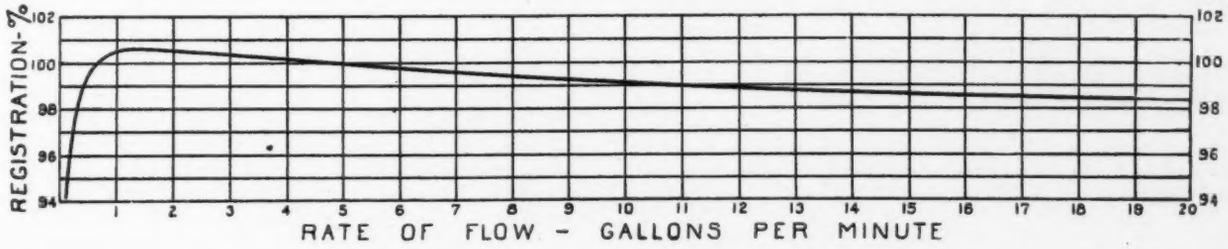
Consultant in Water Works Management, Glen Ridge, N. J.

A typical registration curve of disc type water meters is shown. In this curve the percentage of the water actually registered during passage through the meter is plotted against the rate of flow in gallons per minute.

The curve as a whole may be shifted upwards or downwards by altering the gearing of the meters but this will not change the general shape of the curve. The curve shown in the figure is drawn for five-eighths inch meters but the corresponding curve for any size of disc meter will have much the same shape in relation to the total range of capacity of the meter. The important fact to observe regarding this curve is the fact that it is a curve and not a straight line. In other words, even above the low flows which the meter will not register, the percentage registered is not the same at different rates of flow.

Importance of Testing at Several Rates of Flow

The purpose of testing a meter is to determine the percentage of the water passing the meter which is registered by it. As explained above, this percentage is normally different at different rates of flow. In routine meter shop practice it is of course impractical to test a meter at every rate of flow under which it will actually operate, and yet we must have assurance that it will register within the limits of accuracy adopted at all of these different rates. We know that a test at a single point on the curve, that is, at a single rate of flow, will not give us the percentage registered at other rates of flow. The curve may be of different curvature depending upon the condition of the meter, and we are making the test because we do not know the condition of the meter. If the clearances in the disc chamber are too great, for example, the meter will not register the low flows well and its curve will drop off too rapidly at that end. If the "control" is not close enough, that is, if the spindle is not held at the proper angle, the meter's registration curve will in all probability go up too high at the intermediate rates of flow. With the multiplicity of parts in a



Curve Showing Accuracy of Meter Registration at Variable Rates of Draught

meter there are of course many other defects which may have various effects upon the performance of the mechanism as a whole.

The endeavor must be to test the meter at the least number of rates which will serve to indicate with sufficient reliability what the performance will be over the rest of its range of capacity. It has been found that in normal practice it is necessary to make a test at each one of three different rates of flow, unless the condition of the meter is already quite well known. In order to obtain reliable information from as few as three different rates of test these rates must be carefully chosen in order to show up the true form of the curve and to know that there are no irregularities in it between the points located by the tests.

The three rates of flow at which a disc meter should be tested are usually termed the "Low" or "Minimum" test flow, the "Intermediate" or "Medium" test flow, and the "High" or "Full" flow.

Minimum Flow Test Requirements

The "Low" or "Minimum" flow test is made in order to determine that the meter does not drop off in registration at any higher rate of flow than economically possible, in other words, the meter must be able to register down to a certain predetermined low rate with sufficient accuracy. The accuracy of registration at low flows depends to a large extent upon the reduction of clearances and at the same time the avoidance of friction in the meter.

The rates of flow called for as "Minimum Test Flow" in the Standard Specifications for Disc Type Meters as adopted by the American Water Works Association and the New England Water Works Association, and reproduced herewith as Table I, are the rates of flow in common use. Different organizations vary somewhat the required percentage of registration at these flows to suit individual views and conditions. The Standard Specifications referred to call for at least 90 per cent registration at minimum test flows. Good manufacturing methods and skillful repair work can be considerably better than this on both new and repaired meters, 94 per cent or 96 per cent being not unreasonable to expect.

TABLE I

Rates of Test Flow. From Standard Specifications for Cold Water Meters, Disc Type, Adopted by the A. W. W. A. June 19, 1921, and by the N. E. W. W. A. Sept. 14, 1921

Size of Meter (Inches)	Normal Test Flow Limits (Gallons per Minute)	Minimum Test Flow (Gallons per Minute)
⅝	1 to 20	¼
¾	2 to 34	½
1	3 to 53	¾
1½	5 to 100	1½
2	8 to 160	2
3	16 to 315	4
4	28 to 500	7
6	48 to 1000	12

Intermediate Flow Test Requirements

The Intermediate test flow should be chosen so as to ascertain that the registration at the high point of the curve does not go too high. The rates should, therefore, be such as to aim for the probable highest point. This will vary with different makes and types of meters but it will usually be found at, or a little higher than, the lower figure given under "Normal Test Flow Limits" in the Standard Specifications—see Table I. For a five-eighths inch meter the table gives 1 gal. per min. and the test flow should usually be from 1 to 2 gal. per min.

If the meter is geared and fitted so as to maintain a good registration at the low and high flows then the difficulty in most cases will be to keep the registration down at the intermediate flow. The flatter that the curve for the meter is, the less need there is for such practice. This is one of the many things to be considered in selecting a meter.

High Flow Test Requirements

The high flow test is considered by some to be the least important. This is unfortunate because it is the quickest and most convenient to perform. The exact rate of flow to be used at this test certainly is less important than with the low and intermediate tests because at rates of flow above the intermediate the curve is not apt to rise or fall so markedly. Many shops use a high test flow equal to the higher figure given under "Normal Test Flow Limits" in the standard specifications (Table I). For a five-eighths inch meter the 20 gal. per min. flow is approximately the maximum rated capacity of the meter. The practical objection to using this figure for the high test flow is that in very few cases will the service pipe and plumbing in a residence pass nearly so high a rate of flow and we are therefore testing at a rate beyond that at which the meter will ever operate. Between 50 per cent and 75 per cent of this high figure is a more logical one to use for testing in routine procedure. At the high flow the percentage registered should again be kept up, as in the low flow, and a minimum of 98 per cent is often specified in accordance with the standard specifications.

Having given consideration to the reasons for choosing each one of the three different rates of test flow it is of course self-evident that it is of equal importance to actually perform the tests at those rates, in other words, to measure with reasonable accuracy just what the rate of flow is during the test and to adjust it to the correct figure.

TABLE II

Discharge of Orifices in Gallons Per Minute. The Smaller of the Two Figures Given in Each Case Is the Discharge of a Sharp Edged Orifice in a Thin Plate. The Larger Figure Is the Discharge with Properly Rounded Edges

Size of Orifice—Inches	———Pressure—Pounds Per Square Inch——— 40	60	80	100
1/32....	0.11— 0.18	0.13— 0.22	0.16— 0.26	0.18— 0.29
1/16....	0.44— 0.74	0.54— 0.90	0.62— 1.0	0.70— 1.2
1/ 8....	1.8 — 3.0	2.2 — 3.6	2.5 — 4.2	2.8 — 4.7
3/16....	4.0 — 6.7	4.9 — 8.2	5.6 — 9.4	6.3 —10.5
1/ 4....	7.1 —11.8	8.7 —14.5	10.0 —16.7	11.2 —18.7
5/16....	11.1 —18.5	13.6 —23.	15.7 —26.	17.5 —29.
3/ 8....	16.0 —27.	19.6 —33.	23. —38.	25. —42.
7/16....	22. —36.	27. —44.	31. —51.	34. —57.
1/ 2....	28. —47.	35. —58.	40. —67.	45. —75.

Importance of Accurately Measuring Flows

The most frequently used means of determining the rate of test flow is with an orifice. No fault can be found with this means if we really know how much water is flowing through the orifice.

The rate of flow through an orifice of a given size depends principally upon the shape of the edges of the hole, the thickness of the plate in which the hole is drilled, and upon the effective pressure acting to push the water through the hole. Rather than to state the size of the orifice it is far more definite to give the rate of flow in gallons per minute, or as the number of seconds to pass one cubic foot, as is done in up to the minute shops.

Table II gives the uncertainties of using orifices which have not been actually tested under fixed and known pressures. For example, a one-sixteenth inch orifice under a pressure of eighty pounds per square inch may discharge as much as one gallon per minute if the inner corners of the hole are properly rounded. On the other hand if the edges of the hole are sharp and square and the plate through which the hole is drilled is thin the discharge may be less than two-thirds of a gallon per minute under the same pressure. Variations in the effective pressure added to the above uncertainties will of course cause even greater indefiniteness in the discharge. At forty pounds per square inch the discharge of the one-sixteenth inch sharp edged orifice may be considerably less than one-half gallon per minute, while an increase of the pressure to one hundred pounds per square inch will produce a discharge through the same orifice with rounded edges of over two and one-half times as much. Such uncertainties as these will greatly nullify the benefits of otherwise careful testing.

The best way to determine that the correct rate of flow is being used is to actually use a watch, and preferably a stop watch, to time the filling of a calibrated can or tank. The test flows should be stated in terms of definite figures, such as gallons per minute, and not in terms of the size of the orifice or the number of turns of the valve wheel.

The figures given in Table II are the theoretical figures as to the discharge in gallons per minute of different sizes of orifices under different pressures. The smaller of the two figures given in each case is the discharge with a sharp edged orifice in a thin plate, or with the edges properly bevelled on the outlet side. The larger figure is the maximum discharge to be expected with properly rounded edges on the inlet side of the orifice plate. These figures may serve as a guide in the choice by trial sizes of orifices to be used for obtaining certain rates of discharge. Actual measurement and timing should be employed to check each one, however. It must be remembered that the pressure which is effective upon the orifice will only be shown correctly by a gage located next to the orifice, and beyond the meter being tested, also that the pressure reading must be taken after the flow has become steady and constant.

*From WATER WORKS AND SEWERAGE, January, 1933.

[1]Now Technical Asst. Secy., American Water Works Assn.

% PROPORTIONEERS, INC. %

9 N. CODDING STREET, PROVIDENCE, R. I.

New York, 20 Vesey St. Chicago, 866 Peoples Gas Bldg. Philadelphia, Tax Service Bldg. Pittsburgh, 1403 Oliver Bldg.

REPRESENTATIVES IN PRINCIPAL CITIES

PRODUCTS—Complete line of chemical solution feeders and dry feeding control equipment for water and sewage plants, Chlor-O-Feeders for hypo-chlorinating constant rate or variable flow water supplies in proportion to flow. Multiple feeding pump units for feeding one, two, three, or more chemicals. Ferr-O-Feeders for feeding ferric chloride. Portable Chlor-O-Feeders for standby or emergency use. Gasoline driven portable water pumping units with built-in Chlor-O-Feeders. Engineering service on proportioning problems.

CHLOR-O-FEEDERS IN WATER WORKS SERVICE

Midget Chlor-O-Feeders for constant rates. Chlor-O-Feeders definitely led the way to low-cost hypo-chlorination making it possible to sterilize even the smallest water supply, safely, and economically. For plants treating up to 1½ million gallons per day hypo-chlorination is practical.

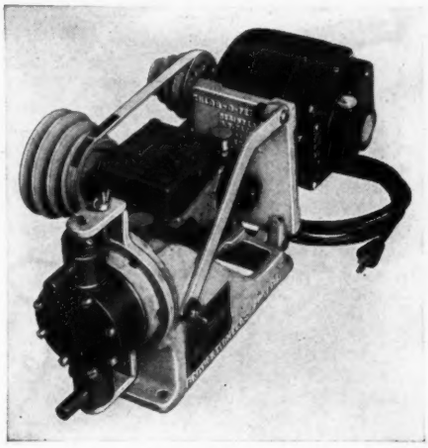


Fig. 1. Midget Chlor-O-Feeder, electric motor driven.

Midget Chlor-O-Feeders (Fig. 1) are furnished for high or low pressure or for feeding into suction side of pump. The device is small; quickly adjusted for different feeds; driven by electric motor, water motor, or by belt connection to water pump drive.

Installation is simple, with aid of instruction book, and operating costs are low as anyone able to operate the water pump is fully capable of running the Chlor-O-Feeder to satisfaction of Health Department.

Fig. 2. DeLuxe Portable Chlor-O-Feeder.

Portable Chlor-O-Feeders—in deluxe form, Fig. 2, mounted and ready to operate anywhere on instant notice; or mounted in hand case for carrying in back of car; are ideal for emergency use; as standby to temporarily replace gas chlorinator; or to augment other units during periods of extreme demand.

Proportional Chlor-O-Feeders for variable flow rates. For many conditions, especially in gravity systems from reservoirs, where flow rates vary considerably from hour to hour, it is essential that Chlor-O-Feeder be controlled by the flow of water so that the amount of solution injected is at all times in proportion.

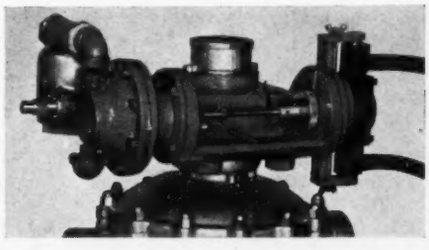


Fig. 3. Proportional Chlor-O-Feeder, meter mounted.

Proportional Chlor-O-Feeder (Fig. 3) can be mounted on and controlled by any flow responsive device; standard water meter of any make, size or type; flow responsive rotor; Venturi Tube; orifice plate; or even the reciprocating parts of deep well pumps can be used to "pull the trigger" that sets off the chlorinating discharge. Chlor-O-Feeder can be operated at any point where the water line can be cut to allow installation of meter. It can be operated entirely by water pressure, so does not require expense of wiring. Operation is simple without the attendance of experts.

pH CONTROL BY CHEMICAL FEEDING

pH control by proportioning lime, soda ash, sodium silicate, sulphuric or other acids, is made simple by use of these flow-proportional chemical feeders. Highly successful installations, designed by leading engineers, are providing permanent relief from plugged and corroded pipe lines.

FERR-O-FEEDER AND CHLOR-O-FEEDER IN SEWAGE PLANTS

Hypo-chlorite sterilization of sewage effluent may be satisfactorily practiced in small sewage plants. Especially suited, too, for CCC camps, summer colonies, and other small sewage systems; chlorinating constantly; manually started and stopped as required; automatically starting or stopping with sewage pumps; or operated, automatically controlled, from sewage syphon. Ferr-O-Feeders feed ferric chloride for treatment of sludge before vacuum filtration; for treating raw sewage, and all kinds of process wastes.

STERILIZING SWIMMING AND WADING POOLS

Public health demands the closest supervision of swimming and wading pools. Triplex Midget (Fig. 4) feeds hypo - chlorite for sterilization —alum for coagulation—and soda ash for pH control; and costs less than the three separate units previously used. In addition to the low cost advantage, the results are better as all three chemicals are kept "in step" with one another at all times.

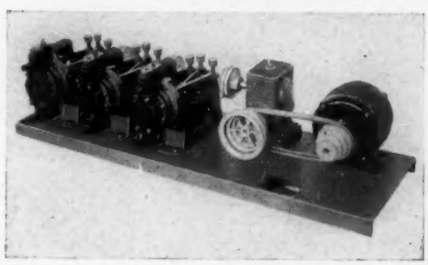


Fig. 4. Triplex Midget Feeder.

ENGINEERING SERVICE ON PROPORTIONING PROBLEMS

Manufacturing feeders for all chemicals and all conditions has enabled %Proportioneers% to acquire valuable experience in this specialized field. This experience is available to you for the asking—correspondence, in detail, is invited.

SELECTING THE RIGHT METER*

By ROGER W. ESTY**

Superintendent, Danvers Water Works, Danvers, Mass.

In days gone by, the thought of "What shall we set for a meter on a service line?" was not given the consideration warranted. The expense involved apparently did not appear to be a factor, because the size of the pipe installed was generally used as the determining factor in selecting the size of meter for the installation.

Since those days meters have reached a much higher degree of perfection and now, at reasonable cost, meters can be purchased to fit any service required; and, can be depended upon to give satisfactory results.

Especial care should be exercised when purchasing a meter because this device serves as the cash-register of the system. When purchasing a meter do not let the price be the determining factor; for, as you know, the older we get the more and more do we realize that you get just about what you pay for. There is no such thing, nowadays, as truth in a claim that "It is just as good for one-half the price."

We must not forget the obligation we owe to those we serve. We must not spend their money recklessly or unwisely.

Several years ago, at Danvers, we had a water waste survey made to check up on our consumption, which apparently was gradually creeping upward without any particular reason. Much to our surprise, we found no unreasonable leakage, but found that all of our large meters were under-registering, some as much as 50 or 60 per cent. On large meters this constitutes a sizeable and serious loss.

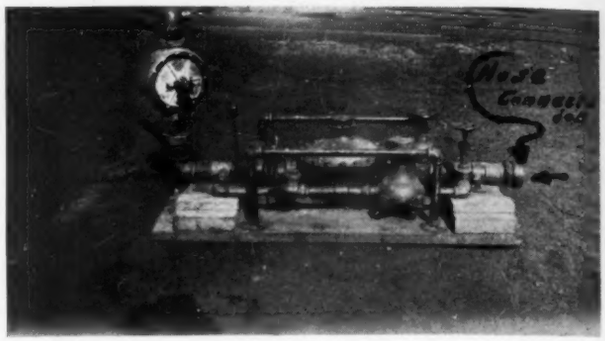
In the past, we never tested these meters. And, as long as they kept running and the monthly readings were comparative little, if any, attention was given them. When we found a stopped one we would take it apart and clean it and make whatever repairs found necessary. We didn't know whether the meter recorded accurately or not. We merely assumed that if it was properly cleaned and repaired it must be right.

After our water waste survey we changed practically every meter. Some we had rebuilt. As time went on we found that this change had been very unsatisfactory. We were suspicious of the accuracy of the readings of one large meter, realizing that its registrations must be too low. To obtain a test on it, we put in two one-inch corporation checks, brought them together, and then from this junction extended a fire hose to a two-inch test disc-meter which had been previously checked for accuracy. From this set-up approximately 200 g.p.m. was obtainable. Apparently our suspicions had been right because we found the meter under-registering. As a result of that test, we started tapping in just beyond all of the other large meters for additional testing.

*Excerpts from an article appearing in WATER WORKS AND SEWERAGE, Sept., 1934.

**The author has the distinction of being now (1936) President of N.E.W.W.A.

Neptune Recording Meter Set, Used in Evalulating Variations in Water Takings by a Customer and Determining the Proper Capacity of Meter



Portable Meter Testing and Flow Measuring Outfit Used in Field Tests

Meter By-Pass Lines Proved Their Worth

From the results of this work, we decided to take out all of our institution and industrial meters, replacing them with new meters. In each case we provided a by-pass line, a test tee and the necessary gates, so that tests and repairs could be made at any time without inconvenience to the customer.

In my opinion the money spent constituted the best investment we have ever made for convenient and money saving maintenance. It is a highly justifiable expense and no meter of any consequence should be set without being provided with a properly gated by-pass with a test plug inserted.

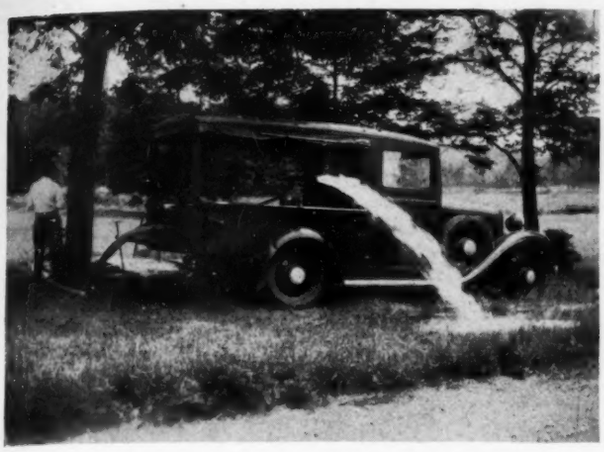
We made mistakes in our first set-up that I would correct if I had to do the work over again. In making changes my first correction would be to set the meter on the by-pass, line and leave the main line unobstructed, to take care of large emergency demands such as would be needed at a fire. As a general rule, a meter much smaller than the size of the supply pipe can be, and should be used and there is also a saving to be had in the cost of the smaller fittings required. This is now the practice followed in Danvers.

Then, next, all gates should be provided with rising stem valves. There is a possibility of leaving gates opened or closed where the standard (non-indicating) gate stem is used. Visualization is a great safeguard and protection and at a glance one can tell the position of a rising stem valve.

Oversize Meters—Why?

After this new set-up of meters had been in for a few years, we made a 3 or 4 day test on each meter, running the recording testing device twenty-four hours each day. The results were surprising—even astounding. Meter line requirements on 6 and 8-inch pipe lines, provided with meters of the same size as the pipe, showed that at no time did the demand exceed on the 6-inch meter 25 g.p.m. and on the 8-inch meter 75 g.p.m.

From these results it was apparent that: In the first case a ¼-inch meter would amply take care of the normal demands on the 6-inch service; and in the second instance a 1¼-inch



Portable Meter Testing Outfit on Service Wagon. Connection Is Made by Fire Hose to Meters Tested

meter would suffice on the 8-inch service. But, these meters were on lines supplying hydrants, and therefore the smaller meters could not be used. It is my opinion, however, that a 4-inch meter—if not a 3-inch meter—will prove ample. A 3-inch meter on a by-pass will supply two powerful fire streams and in most cases this will be sufficient. If a greater demand should be required the main line can be opened. Since we have a man who answers every fire alarm, he has been instructed in every instance to open up the gate on the unmetered side, regardless of how small the first might be.

We have had these smaller meters in now for nine years and we have only opened up the unmetered side of the line once. At this fire only one stream was used, but the gate was opened just the same. No difference was noticed in the volume in this instance, where a 3-inch meter had been cut into a 6-inch line leading from an 18-inch main.

What Size Service Line?

When laying a service main I thoroughly believe in laying one that will more than take care of the service demanded. Larger lines reduce friction and deliver volume up to the point of the demand. The owner should be interviewed regarding what he feels will be his maximum demand in gallons per minute. On commercial lines, I try to have the customer visualize a barrel and then tell him that that barrel holds 50 gallons. Then I ask, how much more or less than 50 gallons per minute will he use? He can readily make a comparison in his mind between the 50 gallons and the amount he is going to use and he can then easily judge about how much he will use, and it is seldom you will find any user using more than "a barrel a minute." Cubic feet means nothing to the customer, and even gallons per minute means little, but the barrel method of determining the amount of water he might use, is much easier for him to understand and has not failed yet in giving to me the information that I have wanted in determining the size of meter and service needed.

The type of service and demand, should be instrumental in determining the type of meter that should be used. Consideration of the small flows should be given prior consideration because 90 per cent of the flows come under the range of the smallest capacities of the large meters. If a large continuous flow is used, then naturally a meter to register large flows should be used as there are no small streams to be considered.

I have a case in my own system, at Danvers, where all of the water is repumped and this pump operates at about 500 g.p.m. until the tank is full, then it automatically shuts off and no more water passes through the meter until the level of the tank drops sufficient to kick in the automatic pump switch. In this case a meter to pick up minor flows, leakage, etc., is not needed, because the rate of flow is 500 g.p.m. or nothing.

The selection of the meter, should in my opinion, be left with the water works officials and *not* to the customer. The ownership of the meter should also be retained by the water department and *not* by the customer. By experience, water works managers are much better qualified than anyone else to select the proper meter which, in justice to all, must be the most adaptable to the desired type of service it is selected for.

R. W. SPARLING

LOS ANGELES
945-951 North Main St.

CHICAGO
3104 S. Michigan Ave.

CINCINNATI
622 Broadway

NEW YORK
101 Park Avenue

Sparling Water Measuring Equipment

Meter in Integral Cast Screw Tube

Rate-of-Flow Indicator-Recorder

Economical
Easily Installed
Sustained Accuracy
Low Pressure Loss
Immune from Frost Damage
Interchangeable Parts
Stock sizes: Two-inch to sixty-inch

Water Meters for Main-Line Service

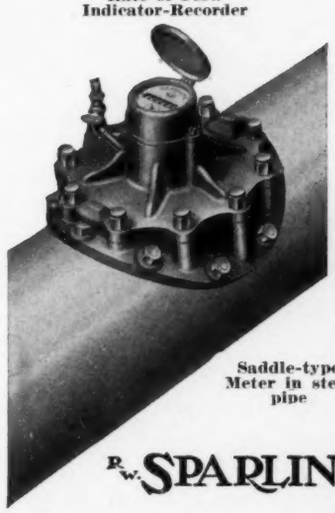
Suitable for pump intake and discharge lines, gravity transmission mains, reservoir inlet and outlet lines, sewage effluence, mill and factory pump mains.

Water Flow Indicators and Recorders

Auto-Metered Controls

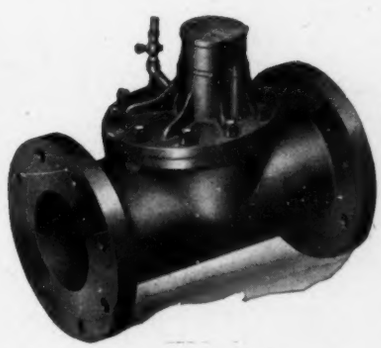
for automatic sampling and feeding.

Send for descriptive Bulletin



Saddle-type Meter in steel pipe

R. W. SPARLING



Flanged Tube Meter

METER TESTING, REPAIR AND SELECTION

By CLEM. A. GALLAGHER

Superintendent of Services, Louisville Water Co., Louisville, Ky.

Recently while making a trip for the purpose of inspecting various meter shops throughout the country, one basic and sad truth struck me bluntly.

That sad truth is simply this: Despite all the progress made in the waterworks field in filtration, pumpage, construction and billing, yes, even in the meter field, a paradox still confronts us. The one sure-fire revenue producing instrument is seemingly neglected, if not ignored. Less, generally, is known about water meters than about any other essential waterworks mechanism. I am of the firm opinion that a definite, efficient, and consistent meter testing and repairing program is a vast asset to any Water Department or Water Company. The revenue accruing naturally from such a program will more than pay the initial expenditure for such a program in the first few years. The difference between 85 per cent and 100 per cent seems not so large arithmetically, but in just one service in one year's time it means many dollars and cents in any language.

Contrary to popular belief a meter testing and repair program is simple in itself. And the cost of such has been grossly exaggerated. By explaining simply, and somewhat in detail, the meter plan we have been working successfully and at reasonable cost in the Louisville Water Company, I hope to prove my contention that a definite, efficient, and concise meter testing and repair program is a vast and lasting asset to any water utility, irrespective of size. Further, that such a program can easily and reasonably be inaugurated and maintained.

The Four Phases of the Program

In such a definite program four phases comprising the composite must be considered and I shall treat of them in order. Meters must be exchanged, tested, repaired. Then, records must be kept of all these operations. It stands to reason that any system which would insure an unfailing and accurate record of a meter, from the time it left the ground until it was returned after testing and repair, would be the most desirable method from every standpoint.

This is our method: We have three men with small trucks exchanging meters daily and returning them to the shop. These men likewise take care of all meter complaints such as meters stopped, broken counters, leaks, etc. Normally each man and his helper will exchange about thirty-five meters a day. A card (here illustrated) has been devised to take care of all of the recording. This card is perforated midway and entwined with a wire at the top. The cards are numbered, and used and filed consecutively. On one side of the card at the top is a record for the meter reset after it has been repaired, tested and O. K.'d. Space is available for the make of meter, the serial number, size, the address set, the attachment number, the account number, the date set. It is signed by the man placing the meter back in the ground.

The lower half of the card on the same side has the record of the meter removed with make, serial number, size, reading, address removed from, attachment number, account number, date removed, reason for removal (exchange, frozen, out of order, etc.), and also space for the signature of the man removing the meter.

On the other side of the card the upper half is blank while the lower half contains a complete record of the meter test and repair. Each meter coming into the shop has this attached card wired to the casing so that this same card remains with that one meter from the time it leaves the ground at one location until it is returned to the ground in another place. This obviates the danger of lost cards and garbled records.

Each meter received in the shop is tested as received and tested, as final, after it has been repaired. Each meter is thoroughly cleaned and repaired irrespective of its first test average. Each 5/8-inch meter is tested with fifty gallons at ten gallons a minute and with ten gallons at one gallon a minute. The meter tester places both percentages on his card as well as the average of the two. The meter is then sent to the repair bench to be cleaned and repaired.

Thorough Shop Records

The lower half of this part of the card contains a list of the repairs made, parts replaced, and the time consumed in this

Meter Repair Shop, Louisville, Ky., Water Works

OMEGA MACHINE COMPANY

4010 Penn, Kansas City, Mo.

PIONEERS IN CHEMICAL FEEDING AND METERING

Advocates of Accuracy and Efficiency

1927 **OMEGA** started with one feeder and a one-man shop. The next year the Universal Feeder was developed, and is still a leader.

1929 **OMEGA** pioneered in the mounting of small feeders on platform scales and large feeders on hopper scales, so that the rate of feed can be regularly and accurately checked. Only dependable and accurate volumetric feeders will stand this sort of test.

1931 **OMEGA** pioneered in the development of improved lime slaking apparatus. The first move was to develop better agitating mechanism. This was followed by insulated slakers and thermostatic control of the water supply. Omega is the only manufacturer urging high temperature slaking, which is absolutely necessary for high efficiency.

1935 **OMEGA** pioneered in the development of Gravimetric Feeders for controlling the rate of feed of dry and liquid materials by weight and not by volume. Realizing that no single type of feeder was suitable for all sorts of conditions, Omega simultaneously developed two types of Gravimetric Feeders.

The Batch type Gravimetric Feeder has a batch hopper on scales, from which material is withdrawn at a rate controlled by the scale mechanism. It is a very accurate unit and is built with hopper capacities up to 10,000 lbs. and feeding capacities up to 3,000 lbs. per hour.

The Belt type Gravimetric Feeder maintains a constant weight of material on the feeder belt and the rate of feed is controlled by changing the speed at which the belt travels. This feeder is particularly well adapted for medium and large rates of feed and for installation in places where the headroom is low and where batch hoppers are not desirable.

1936 **OMEGA** pioneered in developing and using dust removal equipment to prevent the escape of dust incident to the filling of feeder hoppers, and today is the only manufacturer regularly advocating such construction. Dust incident to the filling of feeder hoppers is a nuisance which can be prevented at small cost.

1937 **OMEGA** pioneered in the construction of volumetric feeders with built-in hopper scales to take the place of the awkward platform scales and overhead hopper scales formerly used to check the delivery from the feeders.

OMEGA pioneered in solution feeders for liquids, particularly in the construction of complete self-contained units without separate solution tanks or jars and other accessories and large feeders for ferric chloride and other liquids. A special feature of the small Omega solution feeders is that they are all equipped with a special gauge by which the exact rate of delivery under operating conditions can be instantly determined. Liquid feeders are made for gravity feed and for pressure feed by an **OMEGA** built-in pump.

1938 **OMEGA** has pioneered by simplifying the batch type Gravimetric Feeder to such an extent that the cost is now well within the reach of hundreds of small plants. With these feeders, guesswork in the feeding of chemicals can be eliminated.

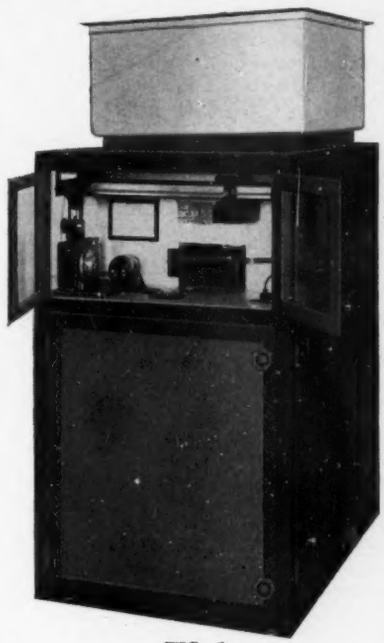


FIG. 1

Gravimetric Feeder, batch type, with extension hopper. A few purchasers listed below:

Cincinnati, Ohio....10	Procter & Gamble Co. 14
Augusta, Ga..... 5	(7 repeat orders)
Springfield, Ill..... 6	

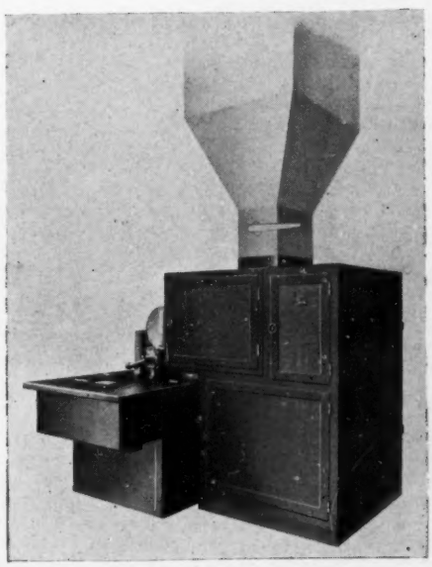
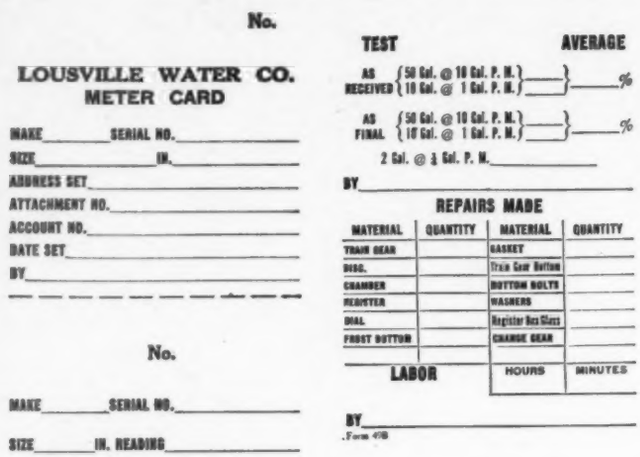


FIG. 2

Gravimetric Feeder, belt type, discharging into an Omega Lime Slaker. A few purchasers of belt type feeders listed below:

Little Rock, Ark... 4	St. Louis Co. Water Co., St. Louis, Mo. 5
Denver, Colo..... 4	(3 repeat orders)
Atlanta, Ga..... 2	

OMEGA is the **only** concern in America engaged exclusively in the manufacture of material metering and feeding devices.



No.

LOUSVILLE WATER CO.
METER CARD

MAKE_____SERIAL NO._____
SIZE_____IN._____
ADDRESS SET_____
ATTACHMENT NO._____
ACCOUNT NO._____
DATE SET_____
BY_____

No.

MAKE_____SERIAL NO._____
SIZE_____IN. READING_____
ADDRESS REMOVED_____
ATTACHMENT NO._____
ACCOUNT NO._____
DATE REMOVED_____
REASON_____
BY_____

OVER

TEST — AVERAGE

AS RECEIVED { 50 Gal. @ 10 Gal. P. M. } ____ } ____%
{ 10 Gal. @ 1 Gal. P. M. } ____ }

AS FINAL { 50 Gal. @ 10 Gal. P. M. } ____ } ____%
{ 10 Gal. @ 1 Gal. P. M. } ____ }

2 Gal. @ ½ Gal. P. M._____

BY_____

REPAIRS MADE

MATERIAL	QUANTITY	MATERIAL	QUANTITY
TRAIN GEAR		GASKET	
DISC.		Train Gear Button	
CHAMBER		BOTTOM BOLTS	
REGISTER		WASHERS	
DIAL		Register Box Glass	
FROST BOTTOM		CHANGE GEAR	
LABOR		HOURS	MINUTES

BY_____

Form 498

Meter Record Card—(Front and Rear) Perforated Across Center for Detaching Lower Half for Recording and Filing. Actual Size of Cards: 8 in. by 3¼ in.

repair. The material is listed on the card with a corresponding space for the quantity of each part used and the bin number from which it was taken. As a consequence, each man while repairing a meter must put down just what new part, or parts, he used, how many parts were used and how long it took him to finish this one meter. The meter repair man then signs the card and the meter is returned to the testing table. It then goes through its final test of fifty gallons at ten gallons a minute; of ten gallons at one gallon a minute, and of two gallons at one-fourth gallon per minute as a final check. The averages are again noted and averaged and this part of the card is then signed by the chief meter tester. If the meter does not register within two per cent it is returned to the bench for a further overhauling. If it, however, registers accurately the card is then severed at the perforation marks and the lower half returned to the meter record office. This card contains, therefore, for the clerks in the meter record department, complete information in regard to this one particular meter including the removal of the same with all statistics, the testing of the same and the repairing of the same. The signature of each foreman definitely places responsibility for errors under each classification. The information from these cards is transcribed to the regular permanent meter cards and the shop tag cards are then filed, according to their test number, in a file to fit this card. This gives the department a test and repair file.

Our endurance test box in the basement is so constructed that it will hold twenty-five meters at one time. It is arranged in a series of two boxes and any meter of any series, either series, or both, can be removed at any time by means of valves without affecting the flow of water in the building. Our figures in many of these tests have been most startling, and seem to prove one thing very conclusively—that the A. W. W. A. specifications for ⅝ inch cold water meters are entirely too lenient. A well constructed water meter should register much better than 90 per cent on a one-fourth gallon per minute stream.

We recently made a meter under-registration survey. We brought into the shop at one time three hundred meters which had been in service five years or longer and tested them as received. The averages were startling inasmuch as the average percentage of inaccuracy on flows for all meters up to and including the one-fourth gallon per minute flow was far above standard requirements, for new meters.

It has been our endeavor in this entire meter program to aim first at thoroughness, but thoroughness through simplicity. We believe we have accomplished our goal and through the cycles described in this paper are able to test and repair water meters regularly, accurately, efficiently and economically. The cost of this program will be as nothing compared with the revenue pickup naturally consequent on such a program—not to mention the life added to the meters.

Any water utility, which neglects to maintain a definite regular meter test and repair program is neglecting what should be considered a water company's greatest asset. As the meters go—so goes your revenue. A water meter *can* be tested, repaired and kept in shape. Like anything else in life, so with water meters—the simplest and safest way is the best and the cheapest way.

The top half of the card remains, of course, on the meter until that meter is again taken out to be reset. Then in like manner the man resetting tthis meter or exchanging it for another fills out the information given above, disconnects the wire and card from the meter, signs the card and returns this reset information to the meter record department. We thus have a complete cycle for our exchange program and by the use of this simple card we have not only a method of double checking each step but also of definitely placing responsibility where it should be placed.

This exchange system, simple as it is, has worked out most successfully for us and should do so for others. The men exchanging meters take out each day just as many tested and repaired meters as they will exchange. This cycle keeps the shop free from meters piling up. At our present speed each of our 50,000 meters will be put through this process once every five years, although our tests (with our water and our meters) show that this period between tests for economy reasons should be lengthened appreciably.

Testing

Next we come to the testing of a water meter. As I have explained above, a meter is tested as received and again after repairs. The size stream for the test depends, of course, upon the size of the meter.

Our meter testing table can test ten ⅝, ¾ or 1 inch meters at a time. On an adjoining bench the larger meters, up to six inches, are tested one at a time. We have done away with the slower method of weighing for tests, and use only calibrated tanks and funnels. A hydraulic plunger keeps the meters in place. This test bench is so arranged that we can vary our stream anywhere from 225 gallons per minute down to 1/320 gallons a minute. The latter is accomplished by means of needle valves.

Recently we have standardized on the sweep-hand dials on all meters, for two very definite reasons. First of all it is much easier to detect a leak on any size meter if it is equipped with a sweep-hand dial, and secondly and even more important, it facilitates the testing of a meter in time saved and assures us that our registers are likewise accurate. We could not be sure of this by the use of test dials. Our meter tester and his helper average over one hundred ⅝ inch meters per day on standard tests. A cycle is likewise completed here, since in the morning meters are tested as final and in the afternoon a new lot is received. Thus the repair men on the bench, work each day on the meters tested as received the previous afternoon while the meter tester tests as final in the morning the meters repaired the previous day.

It is noteworthy that our records show that less than one percent of the total number of meters repaired have been unfit after repair, and have to be returned to the bench. The promiscuous use of change gears is undesirable and we try to get away from it as fully as possible.

Repairing

The next step in our meter routine is our repair bench. Five men work on this bench and each man has his own set of tools, his own sink with running hot and cold water, his own brushes and a hose with a stop-valve carrying compressed air of about seven to ten pounds pressure. This air is simply piped from our garage and reduced in the meter shop by means of a reducing valve. We have found that this compressed air at this pressure is most useful and practical for testing out the running smoothness of a meter as well as ejecting particles which may be holding back the best performance of a meter. It likewise does away with the necessity of the men placing their mouths on the outlet or inlet to a meter.

The meter bench is made of wood and covered with heavy galvanized iron. Above each man is an electric reflector which evenly lights up his place of work just where he needs it most. Each meter is placed in a separate pan to do away with the loss or mixing up of parts.

Our manner of cleaning a meter is simply the old fashioned but effective soap and water method. We deprecate the use of acid on any meter, or parts thereof, unless it is absolutely necessary. We have found that under our own water conditions the encrustation can be satisfactorily and more safely removed by good old hot water, soap, and elbow grease. We do no machining or reboring because, generally, replacement is cheaper and safer from every angle. Above the repair benches are marked and lettered compartments for the various parts of any

size or make of meter. This is part of our permanent running inventory system. Each closed bin contains a different part and each bin is numbered. When the men need any new part for any meter they must mark on their ticket the number of such parts used as well as the bin number from which it was taken. A regular inventory clerk can thus keep, from these cards, a daily record of just what parts were used and how many of each part remains in stock. He has a standard minimum of each part that should be kept in stock. He can daily or on a moment's notice notify the department head just what parts are needed and how many of each, and they are then requisitioned and ordered. Again this inventory system, though simplicity itself, affords an easy check on costs, new parts required, etc.

Each man averages between fifteen and twenty meters a day, completely cleaned and repaired. The average cost, not including overhead, runs about fifty cents a meter for tests and repairs. We use about fifty new discs a month. Bottom bolts and gaskets most often need replacement. A meter is scrapped only after it is completely a liability. We have returned to service meters, after overhauling and cleaning, which have been in the ground forty years and more. One man at another bench takes care of the registers, setting back to zero, lubrication, etc. We solder the counters and thus avoid ruining the gears by running counters back speedily with a motor driven disc. After cleaning, the registers of all meters are then dipped in hot oil and drained. This oil is fine, and not too thick for frigid weather. The meter shop is kept clean and each man knows just what he must clean up before he leaves. The work has been divided. The floor is waxed and a heavy, linked rubber carpet stretches all along the repair and test benches. On Saturday of each week larger meters, from one inch to six inch, are tested and repaired. Of course this work is slower and more tedious than that on 5/8 inch meters. A healthy spirit of competition, a desire to keep the meter shop clean and a pride in repair average, can work wonders if engendered and encouraged.

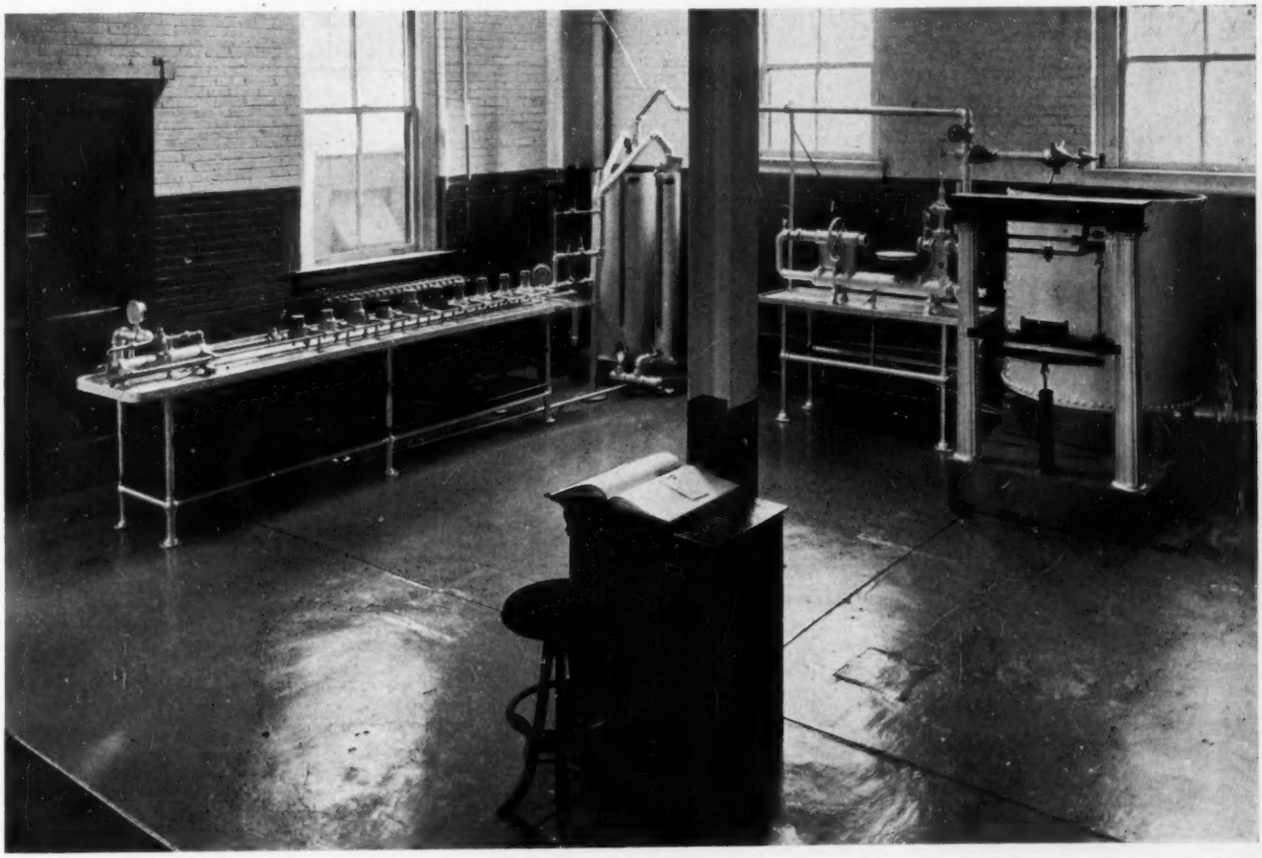
Meter Recording Office

On the same floor is our enclosed meter record office. The head of the Meter Department and clerks keep all records of all meters. We keep two cards on each meter—one according to make and serial number and one according to the book and page number in the meter readers' books. All information—address, make, size, serial number, purchase date and price, sets and resets, tests and repairs, are kept on these cards. Any information concerning any meter in service at any address, any meter in the stock room, or in the shop, is available at all times. The city is divided into districts, lettered alphabetically, and a reference from card to meter books gives all information concerning reading, leaks, etc. The two sections of the numbered cards are filed separately after the information thereon has been transcribed to the other set of cards. These test and repair cards give the final shop information on any particular meter. This system of checks and balances assures accuracy, permanency, and simplicity. All necessary information is always at hand and any meter can be traced from the moment we receive it until we scrap it. We are at present about 75 per cent metered and have in the ground approximately 50,000 meters.

Selecting Meters

When purchasing a water meter three things must be taken into consideration, namely, accuracy, endurance, and interchangeability. It was our desire to find out just what meters would be most dependable under Louisville water conditions and with this idea in mind we have been conducting a series of tests with new stock meters. Ten of each make are tested at a time. The new meters are tested, as received, on flows of ten gallons a minute, one gallon a minute, one-fourth gallon a minute and one-twelfth gallon a minute. These same ten meters are then placed in an endurance test box in the basement and the water used in our building allowed to run through them until they register an average of five hundred thousand (500,000) gallons. We can vary this flow in the building as desired.

They are then taken back to the shop and retested exactly as above. The figures are then averaged, with emphasis on the average percentage of inaccuracy, and blue prints are made of the records for permanent filing Next, these meters are taken apart and thir parts interchanged. They are run then for approximately one hundred thousand gallons and retested again according to the former specifications. Finally they can be run on an absolute endurance test, which of course takes time, until one or more meters in any series breaks down. Faulty meters are taken apart and the cause of such break down investigated.



Testing Benches and Equipment, Meter Shop, Louisville, Ky., Water Works

LIQUID CHLORINE*

Properties of Chlorine

Chlorine is never found free in nature. Gaseous chlorine is manufactured by the electrolysis of a sodium chloride solution. It is then purified and liquefied by a process of compression and refrigeration. As an article of commerce, chlorine is an amber-colored liquid approximately one and one-half times as heavy as water. It is marketed in steel containers which are under pressure. In Fig. 1 is shown the relation between temperature and vapor pressure.

When the pressure is released, liquid chlorine volatilizes into a greenish-yellow gas which is approximately two and one-half times as heavy as air. Chlorine is non-inflammable, non-explosive, and a non-conductor of electricity. Generally speaking, in the absence of moisture it is not corrosive to common metals. In the presence of moisture gaseous chlorine reacts avidly with a majority of known substances.

Following is listed the more important chemical and physical properties of chlorine at standard conditions (32° F. and 1 atm. pressure) unless otherwise noted:

	Atomic	Molecular
Chemical Symbol for Chlorine....	Cl	Cl_2
Chemical Weight Relationship...	35.457	70.914
	Gaseous Chlorine	Liquid Chlorine
Specific Gravity	2.49* (air = 1)	1.47† (water = 1)
Weight per Cubic Foot...	0.201 lb.	91.70 lb.
Volume per Pound	4.98 cu. ft.	0.011 cu. ft.
Specific Heat		0.2230†
Liquefying Point		— 28.5° F.†
Freezing Point		—151.6° F.‡
Latent Heat of Evaporation		121.0 B.t.u.†
Critical Temperature		294.8° F.†
Pressure at Critical Temperature		1233 lb. per sq. in.
1 Volume Liquid		456 vol. gas

*Leduc †Kneitsch ‡Lange

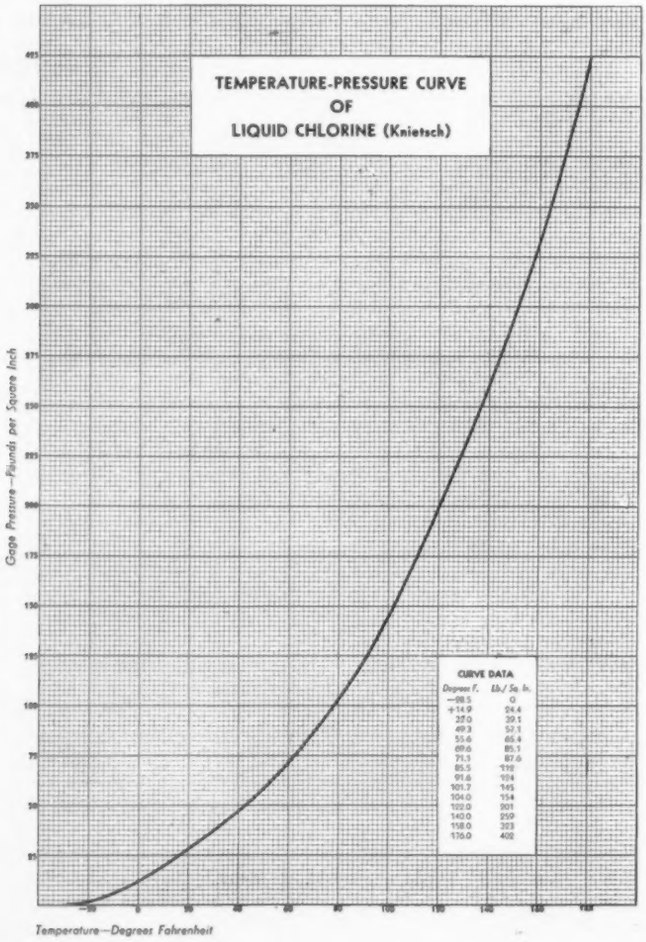


Fig. 1—Relation between Temperature and Vapor Pressure

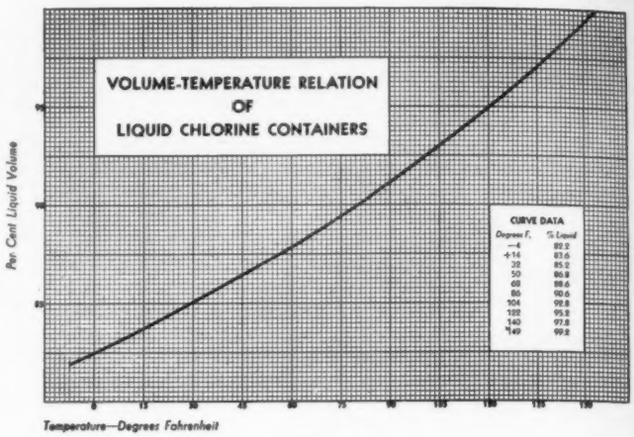


Fig. 3

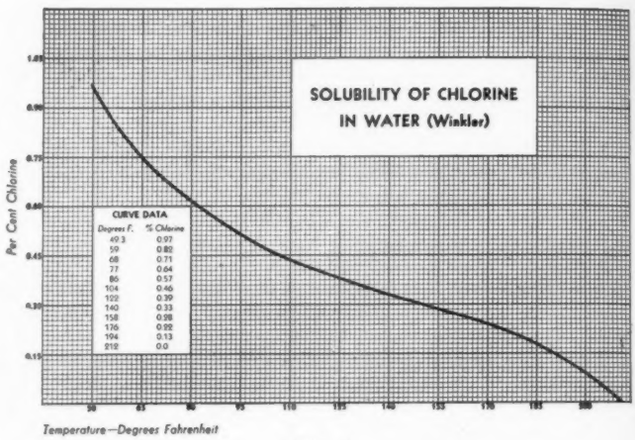


Fig. 4

A better visualization of those properties which are more serviceable can be obtained by studying the following charts and tables.

The compressibility coefficient of liquid chlorine is more than that of any other liquid element (approximately 0.0118% vol. /atm.). Its density decreases quite rapidly with increasing temperature. It is obvious from an examination of Figure 3 that above 156° F. a cylinder loaded to legal limits is subjected to hydrostatic pressure which will rupture it. Therefore, it is most important that the cylinder be kept safely below this temperature in any circumstances.

Chlorine is only slightly soluble in water. As depicted by Figure 4, its maximum solubility in distilled water is approximately 1% at 49.2° F. Below that temperature chlorine crystallizes in the form of chlorine hydrates, their composition depending upon conditions.

Liquid Chlorine Containers

Cylinders

Cylinders for shipping liquid chlorine by express, less carload, or box carload freight, are of various sizes ranging from 10 pounds net to 150 pounds net.

WEIGHTS OF 100 AND 150-LB. CYLINDERS

Net Contents	100 pounds	150 pounds
Average Tare Weight	93 pounds	123 pounds
Average Gross Weight	193 pounds	273 pounds

Minimum carloads comprise one hundred and fifty 100-pound cylinders or one hundred and eleven 150-pound cylinders.

Figure 6 illustrates the standard chlorine cylinder valve designed by the Chlorine Institute and now used by nearly all chlorine shippers. The stem "A" is of Monel metal and one complete turn in a counter-clockwise direction opens the valve so as to permit the maximum discharge of gas. A "frozen"

*From a bulletin on "Liquid Chlorine," prepared and distributed by Pennsylvania Salt Mfg. Co., March, 1936.

THE MATHIESON ALKALI WORKS (INC.)

60 East 42nd Street, New York, N. Y.

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MATHIESON LIQUID CHLORINE

Water works operators have been specifying "Mathieson" since the pioneer days of shipping liquid chlorine. Increasing quantities are also being used for sewage chlorination throughout the country. For sterilization of swimming pools, Mathieson Chlorine assures safety through trouble-free operation.

Modern container equipment, regularly inspected and conditioned, safeguards the original purity of Mathieson Chlorine. Every container is checked and rechecked to safeguard the purity of the product and insure all equipment arriving in perfect order. All valves, threads and other container parts must be clean, accurately placed and in efficient working condition. Convenient warehouse stocks of Mathieson Chlorine make it immediately available.

Mathieson Liquid Chlorine for water works use is shipped in a special group of aluminum-painted standard steel cylinders of 105 and 150 pounds net. In addition to standard cylinders, multi-unit tank cars carrying 15 one-ton container units have become increasingly popular among large municipal consumers.

Handling Chlorine Safely

To assure safety and efficiency in the handling of chlorine containers, Mathieson offers free of charge to chlorine consumers an attractive wall chart containing information that will eliminate needless hazards and remove unfounded fears. We shall be glad to supply you with one or more of these wall charts to post in appropriate locations.

MATHIESON ANHYDROUS AMMONIA

To water works, swimming pools, etc., using the ammonia-chlorine treatment, Mathieson's unique position as a producer of *both* liquid chlorine and anhydrous ammonia is particularly advantageous. Ordering is more convenient—receipt of shipments and return of containers is simplified. Technical assistance comes to you from those competent to discuss both products.

Meeting the highest published specifications for purity, Mathieson Anhydrous Ammonia is shipped in container equipment which receives the same careful servicing and checking, accorded to that for Mathieson Liquid Chlorine. Mathieson Ammonia is available in 50-lb., 100-lb., and 150-lb. cylinders from 46 warehouse stocks throughout the country and at eight convenient base points.

H T H

True Calcium Hypochlorite

While liquid chlorine will no doubt continue to be the chief source of supply for large scale chlorination operations, H T H solves many a treating problem where difficulties of transportation and application make liquid chlorine either impractical or uneconomic. Simple equipment for proportioning feed of hypochlorite solutions made from H T H has widened the range of usefulness for this product for continuous chlorination of smaller water supplies. Moreover, at both large and small water works, H T H meets the requirements of a reliable emergency or stand-by source of chlorine as no other material is capable of doing.

H T H is a true calcium hypochlorite ($Ca(OCl)_2$) containing over 70% available chlorine. It is a dry, free-flowing powder which dissolves quickly in water. Extremely stable, H T H keeps its strength even after months of storage at summer temperatures.

The 3¾-lb. cans of H T H, packed 12 to the case, are particularly convenient for hypo-chlorination of pipe lines, isolated water supplies and at locations where transportation of the chlorine carrier is a troublesome factor. For continuous or emergency hypo-chlorination of water supplies, the 75-lb. drum is an economical package.

Hypo-Chlorination of Water

"Hypo-Chlorination of Water," an 80-page handbook by Walter L. Savell, contains a complete discussion of such water treatment problems as: Combating algae and slime growths; conditioning filters, sterilizing filter sand; disinfecting new reservoirs, basins, tanks; sterilizing water mains; feeding hypochlorite—selection of equipment; insuring safety in emergencies. It also contains a section devoted to hypo-chlorination in sewage disposal and a section on practical swimming pool sanitation. We shall be glad to send you a copy of this handbook free of charge.

OTHER MATHIESON CHEMICALS

Light Soda Ash—58%. Shipped in 100-, 150-, 200-, and 300-lb. bags; 300-lb. barrels, and in bulk.

Caustic Soda—76%. Solid caustic shipped in 730-, and 700-lb. drums. Flake caustic shipped in 50-, 100-, and 400-lb. drums.

PH-Plus (Fused Alkali). A special moisture-free alkali for water treatment, fused at 2,200° C. and cast in ½-lb. conical cakes. The cakes have a purity and rate of solution particularly desirable for pH control of swimming pool water and general industrial water treatment. In drums of 115 lbs. net, in 200-lb. bags, and in barrels of 350 lbs. net.

Bleaching Powder. Available chlorine content—35-37%. Shipped in special galvanized steel drums of 333 and 825 lbs. average net weight.

C C H (Industrial Hypochlorite). Water works consumers planning to use substantial quantities of hypochlorite for water or sewage treatment are invited to consult with the Mathieson technical staff concerning the possible use of C C H, an industrial hypochlorite containing over 70% available chlorine.

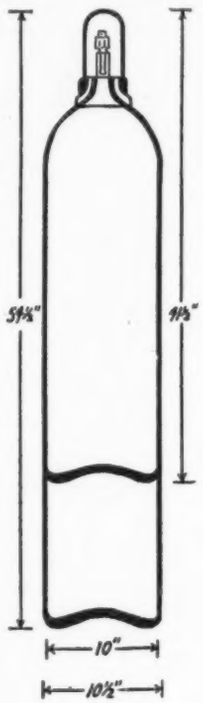
stem can usually be freed by slightly loosening the packing nut "C," tapping the top of the stem lightly, and then giving the valve wrench a sharp rap with the palm of the hand. The body "B" is a bronze and all connections to it are tightened by turning in a clockwise direction. Gas leaks around the stem can be checked by tightening the packing nut. *Under no circumstances tamper with safety plug "D."* It is below the valve seat and, therefore, cannot be controlled by the valve. Fusible metal in this plug softens at temperatures exceeding 157° F., hence cylinders should never be exposed to such temperatures for even short durations.

The valve outlet threads are standard ¾-inch hose coupling to which an auxiliary valve (containing a fiber or lead gasket) may be connected. However, these threads are bronze and are easily damaged. The clamp and adaptor shown in Figure 7 is the more practical type of connection.

Handling Cylinders

The handling of cylinders requires no expensive equipment. It is preferable that they be transported and stored in an upright position. Light, rubber-tired, two-wheeled trucks are convenient for moving them on level floors. Where cylinders have to be lifted above the ground floor a crane, or hoist, equipped with a special cradle, or carrier, should be provided in the absence of an elevator.

The maximum discharge rate of chlorine gas at 70° F. is approximately 35 pounds per 24 hours for a 100- and 150-pound cylinder. This rate may be increased by improving the circulation of air around the cylinder, or by raising the temperature. Under no circumstances should the application of heat be made directly to the fusible plug. The practical method of heating cylinders is by means of a thermostatically controlled water bath in which the temperature is limited to 100° F. Even this procedure is questionable if used in conjunction with a chlorinator because uneven temperatures prevail which in turn cause condensation difficulties. Where chlorine is used in equipment operating under cylinder pressures, it is essential that the cylinder temperature be no higher than that of the gas lines or chlorinator. Otherwise condensation will certainly occur with attending operating irregularities. (See Fig. 9.)



Cross Section of 100- and 150-Pound Cylinders

Fig. 5—Various Sizes of Cylinders

As soon as the cylinder is emptied, suction is set up tending to draw water and foreign matter back into the cylinder. This has caused several cylinder failures which could have been avoided by closing the cylinder valve as soon as the cylinder is empty.

Multiple Unit Tank Cars—Ton Containers

The multiple unit tank car is adapted for large chlorine consumers who desire a more flexible unit than the standard chlorine tank car. It consists of an underframe carrying 15 one-ton drums. Classed as a tank car, the underframe and units are subject to free freight movement both ways, freight being assessed only on the net contents of the car.

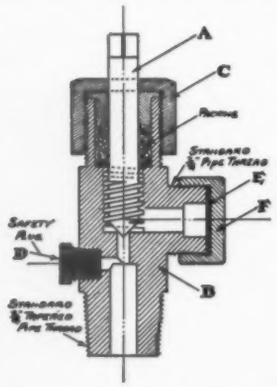


Fig. 6—Cross Section of Standard Cylinder Valve

Each of the unit containers holds 2000 pounds of chlorine. *This shipping container is authorized by the Interstate Commerce Commission for common carrier movement only as an integral part of a fifteen unit car. Multiple unit and tank cars may be consigned only to private sidings, or to approved public sidings.* (*Par.* 431*B I. C. C., Regulations as amended* 1933.) Where unloading conditions are ideal it is a useful package of chlorine because its units are of such size as to permit reasonable movability yet not requiring the frequent changing necessary when using small cylinders.

Each container is equipped with 2 valves, 2 internal eduction pipes, 3 fusible (157° F.) safety plugs in each end, and a removable valve hood. The valves are identical with the standard cylinder valves, except they are provided with larger internal valve openings and are not fitted with safety plugs.

Multiple unit tank cars are not recommended for plants using less than 200 pounds of chlorine per day.

Handling Ton Containers

Due to the size and weight of ton containers, special equipment is required for unloading and transporting to storage or service rooms. Stationary or movable cranes, travelling overhead rail hoists, trucks, and dollies have been employed to meet the peculiar needs of individual plants. Some type of lifting rig is necessary for use with cranes or hoists.

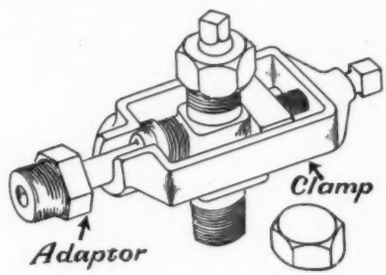


Fig. 7—Clamp and Adapter

Containers are more easily handled and serviced from a prone position. Before servicing the container should be rolled or adjusted so one valve is directly above the other as shown in Figure 12. In this position, liquid chlorine may be discharged from the bottom valve and gaseous chlorine from the top valve. Some plants concerned only with the application of gaseous chlorine prefer to up-end the containers for storing and servicing, which procedure produces material saving in floor space.

The clamp and adaptor connection previously illustrated is recommended as the most practical and flexible connection for container valves. Wrenches for operating these valves should never be longer than seven inches.

Four hundred and twenty pounds per 24 hours is approximately the maximum rate of gas withdrawal for a ton-container at 70° F., operating against 35 pounds per square inch back pressure. This rate may be increased by improving the air circulation around the container, or by raising the room temperature. *Ton containers should never be subjected to the direct application of heat because of the danger of melting the fusible plugs.*

Single Unit Tank Cars

Single unit chlorine tank cars are of two sizes, holding approximately 32,000 and 60,000 pounds of chlorine each. Located in the dome are two liquid withdrawal valves on the longitudinal axis, two gas valves on the transverse axis, and a safety valve. Each liquid eduction pipe is fitted with a vertically acting ball check which stops the flow of liquid chlorine from the car in case of unloading line breakage, sudden opening of valve, or very heavy withdrawal rates.

The withdrawal of gaseous chlorine from any liquid chlorine container causes refrigeration and subsequent pressure reduction in the container. This effect is markedly increased by the cork insulation on single unit tank cars, and consumers purchasing their chlorine requirements in single unit tank cars may find it necessary to use liquid chlorine vaporizers on their operation requiring chlorine gas. Vaporizers usually employ hot water or steam as their heat sources, and may be equipped with either open or closed jackets.

Piping and Fixtures

A copper tubing built for 500 pounds per square inch working pressure is the preferred material for connecting all chlorine containers to permanent pipe lines.

Dry Chlorine

Black iron pipe is recommended as the preferable material for dry gaseous or liquid chlorine, although steel, copper, or other metal piping which will resist high pressures may be used. While standard weight pipe is satisfactory for all normal chlo-

PENNSYLVANIA SALT MFG. COMPANY

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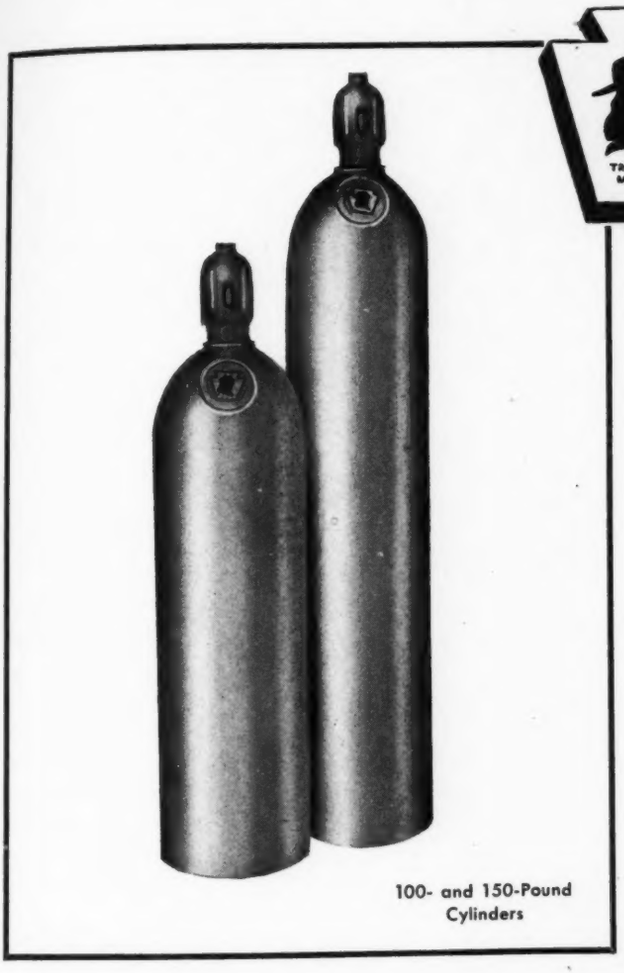
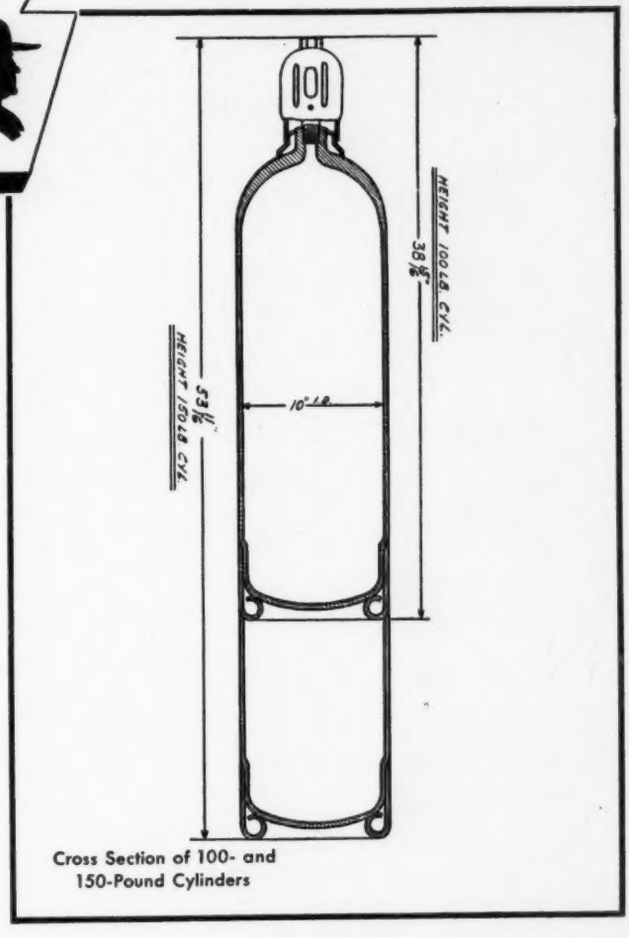


100- and 150-Pound Cylinders



Cross Section of 100- and 150-Pound Cylinders

LIQUID CHLORINE

High purity and uniform quality are notable features of the liquid chlorine produced by Pennsylvania Salt Manufacturing Company for water purification and sewage treatment.

This is chlorine particularly free from "taffy," the familiar sticky substance that often causes chlorinator irregularities. An important constituent in "taffy" is *hexachloroethane,* which has been eliminated almost completely from the liquid chlorine produced by this Company.

The result is that "taffy" troubles due to the quality of the chlorine are materially reduced when you use this extremely pure product. It is promptly available in any desired quantity. We will gladly quote on your requirements.

Other water purification and sewage treatment products:

PERCHLORON
AMMONIA
FERRIC CHLORIDE
FILTER ALUM

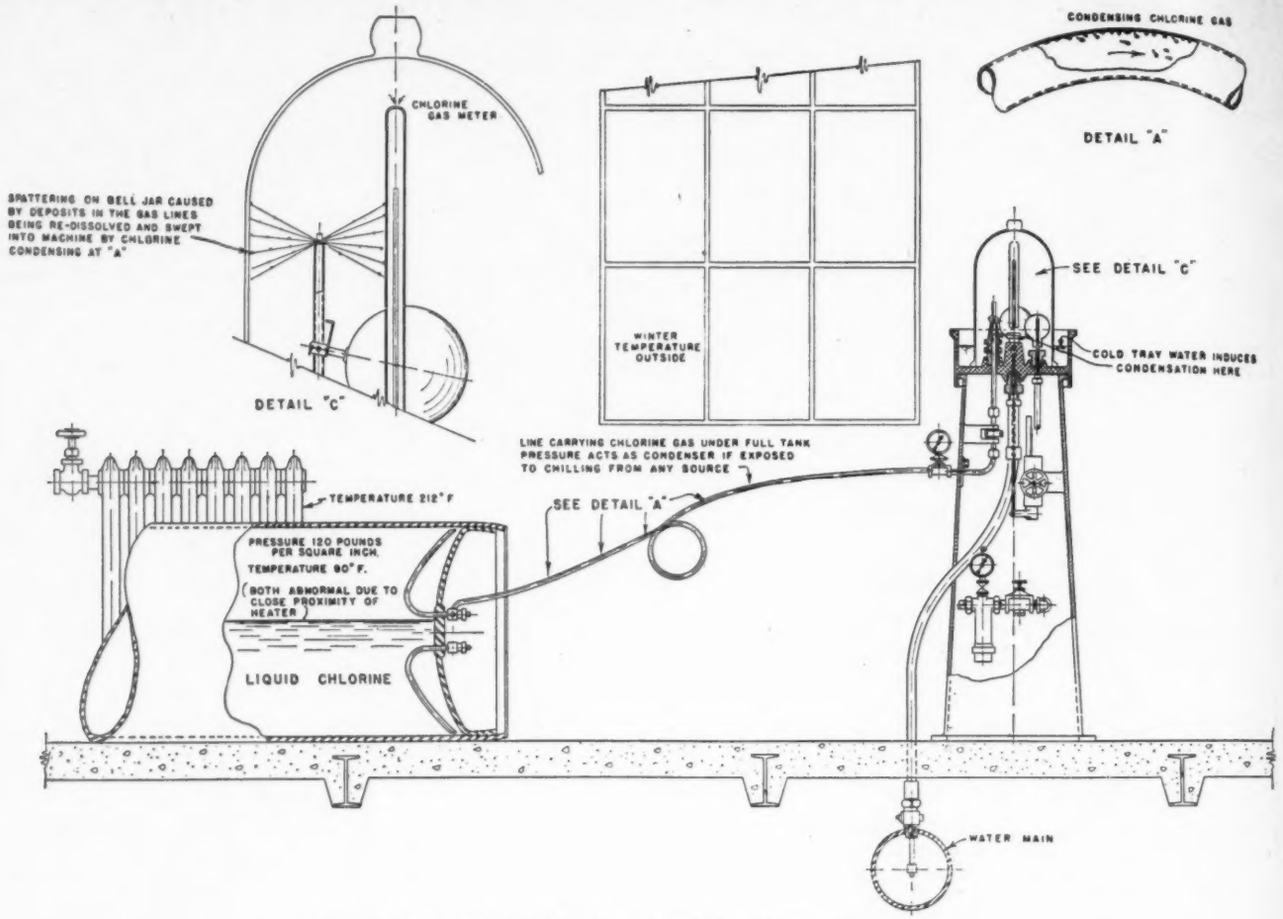

CONDENSING CHLORINE GAS
DETAIL "A"
CHLORINE GAS METER
SPATTERING ON BELL JAR CAUSED BY DEPOSITS IN THE GAS LINES BEING RE-DISSOLVED AND SWEPT INTO MACHINE BY CHLORINE CONDENSING AT "A"
DETAIL "C"
WINTER TEMPERATURE OUTSIDE
SEE DETAIL "C"
COLD TRAY WATER INDUCES CONDENSATION HERE
LINE CARRYING CHLORINE GAS UNDER FULL TANK PRESSURE ACTS AS CONDENSER IF EXPOSED TO CHILLING FROM ANY SOURCE
SEE DETAIL "A"
TEMPERATURE 212° F
PRESSURE 120 POUNDS PER SQUARE INCH.
TEMPERATURE 90° F.
BOTH ABNORMAL DUE TO CLOSE PROXIMITY OF HEATER
LIQUID CHLORINE
WATER MAIN

Fig. 9—Condensation Difficulties Caused by Uneven Temperatures

rine pressures, the extra heavy variety is recommended as safer and more practical since abnormal temperatures caused by fires, mechanical strains due to displacements, and corrosion produced by the entrance of moisture are all factors which should be considered. Liquid chlorine lines should be as free from bends and obstructions as possible. Where maximum discharge rates or lifts are required, pipe friction losses should be reduced by using lines of ¾ inch or more in diameter.

Hard rubber pipe is satisfactory for chlorine gas, but should never be used for conveying liquid chlorine. Pressure should not exceed 50 pounds and 80 pounds for the standard and extra heavy hard rubber pipe respectively. *Lines conveying gaseous chlorine should be run on a continuous upgrade in order that condensed (re-liquefied) chlorine will run back into the container.* Where this is impractical, drip legs should be provided in the low points of the pipe line. These legs should terminate in pockets which will assure evaporation of the liquid chlorine. *Blow-off cocks or other bleeding arrangements are not recommended since they are both dangerous and unnecessary.*

Pipe joints may be made with standard couplings, unions, or flanges. Standard ammonia flanges are preferable, since their use permits easy inspection and repair to lines. Gaskets should be of lead or asbestos composition. Only special valves for chlorine service should be employed. Usually, the body is of steel or special bronze, and the stem is of Monel metal. Graphite coated asbestos and rubber covered asbestos are recommended for packing. Flanged valves are preferable. Gauges should be of the diaphragm type for chlorine service. *Equipment and lines carrying dry chlorine should not be exposed to excessive heat.*

Wet Chlorine

Wet chlorine is very corrosive to all of the common metals. Materials contacting it must be of earthenware, glass, rubber, one of the special alloys, or noble metals. The handling of wet chlorine is an individual plant problem and specific recommendations can be made only after a survey and study of the various factors involved.

Handling Chlorine Leaks

(The safety information in the following paragraphs has been taken largely from Sale Practices Pamphlet No. 71 of the National Safety Council, as recommended for revision by The Chlorine Institute in December, 1935. For more complete safety information write the National Safety Council, 20 North Wacker Drive, Chicago, Illinois.)

The ventilation provided for the chlorine room, mechanical or otherwise, should be of such nature as to remove and dissipate the gas with the least injury to persons and property.

Stand leaking container upright if possible. This will prevent the escape of liquid chlorine and under these conditions vaporization diminishes rapidly as natural chilling takes place and the escape of chlorine into the air will then be very slow. Ton containers have two valves, and in case of a leaky valve, the container should be rolled so the valves are in vertical plane with the leaky valve upward. In this position the valve will leak chlorine gas, not liquid chlorine.

In case of accident indoors, every effort should be made to remove the leaky container outside the building. *Water played on a gas tank will not stop the leak.* Water in large quantities played on a cylinder gas leak will assist in diluting and dissipating the gas. Water played on a liquid leak may provide

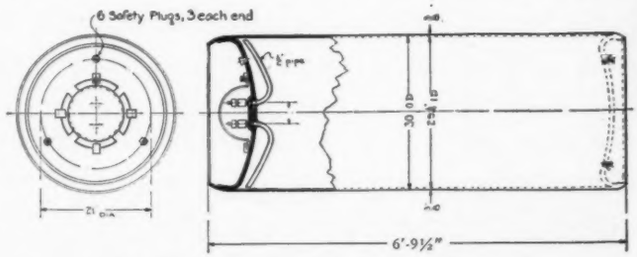


Fig. 12—Cross Section of a Ton Container

THE COLUMBIA ALKALI CORPORATION

BARBERTON • OHIO

NEW YORK CHICAGO BOSTON PITTSBURGH
CLEVELAND CINCINNATI ST. LOUIS MINNEAPOLIS

COLUMBIA LIQUID CHLORINE

Production of COLUMBIA Liquid Chlorine takes place in a modern plant with the most approved equipment, assuring the consumer a product of full strength, purity and uniformity. The importance of these qualities for water purification and sterilization of swimming pools is obvious. For sewerage chlorination, COLUMBIA Liquid Chlorine is also well-suited.

SHIPPING UNITS

30 ton single unit cars.
16 ton single unit cars.
15 ton multiple unit cars.
150 and 100 lb. cylinders.

The equipment for the distribution of COLUMBIA Liquid Chlorine conforms with standards of the Interstate Commerce Commission and The Chlorine Institute. The latest and best type of cylinders are used, as exemplified by the fact that the COLUMBIA 100-lb. cylinder is seventeen pounds lighter than others commonly used, and the 150-lb. COLUMBIA cylinder is twenty-nine pounds lighter than the ordinary type of cylinder used. This is due to the fact that modern type pressed steel construction is used.

TECHNICAL SERVICE

COLUMBIA offers its customers the facilities of its Technical Service Department which includes on its staff engineers experienced in chlorination problems of installation and operation. A new laboratory has recently been completed at the Barberton plant. It provides the staff with the latest equipment for testing and research.

OTHER COLUMBIA PRODUCTS

SODA ASH
99 - 100%
LIGHT FEATHER DENSE

CAUSTIC SODA
SOLID FLAKE POWDERED LIQUID

SODIUM BICARBONATE
U.S.P. TECHNICAL AND GRANULAR

MODIFIED SODA

CALCIUM CHLORIDE
FLAKE LIQUID SOLID

chlorine hydrate from which the evaporation of gas is slow. These operations should only be undertaken by a competent person wearing an approved gas mask in good order. When a pond or large body of water is nearby, the leaking container should be submerged in the water. Loose earth, cement, lime (both slaked and unslaked), and heavy textiles (both wet and dry), such as bagging and felt, will act as an absorbent or blanket.

It is illegal to ship a defective or leaking chlorine container. If there is an accident, telephone the car owner or nearest chlorine plant for assistance. The telephone numbers and residence addresses of the nearest chlorine plant organization members should be posted in the office of the person in charge of the handling of chlorine in the plant of the user, and in the office of the manager.

Gas Masks

It is imperative that some form of protection be provided for emergencies. Several types of gas masks approved by the U. S. Bureau of Mines and suitable for high concentrations of chlorine are available. For this purpose, a sufficient number of suitable gas masks should be on hand and located at a readily accessible point outside the area likely to be affected in case of accident. The instructions accompanying a mask concerning its care and use should be obeyed implicitly. Everyone who is in danger of being accidentally exposed to high concentrations of chlorine should be provided with a gas mask, preferably to be used by no one else. He should be familiar with the instructions accompanying it and trained to hold his breath and to put the mask on quickly and properly. Periodic strict inspection and maintenance of approved gas masks are essential.

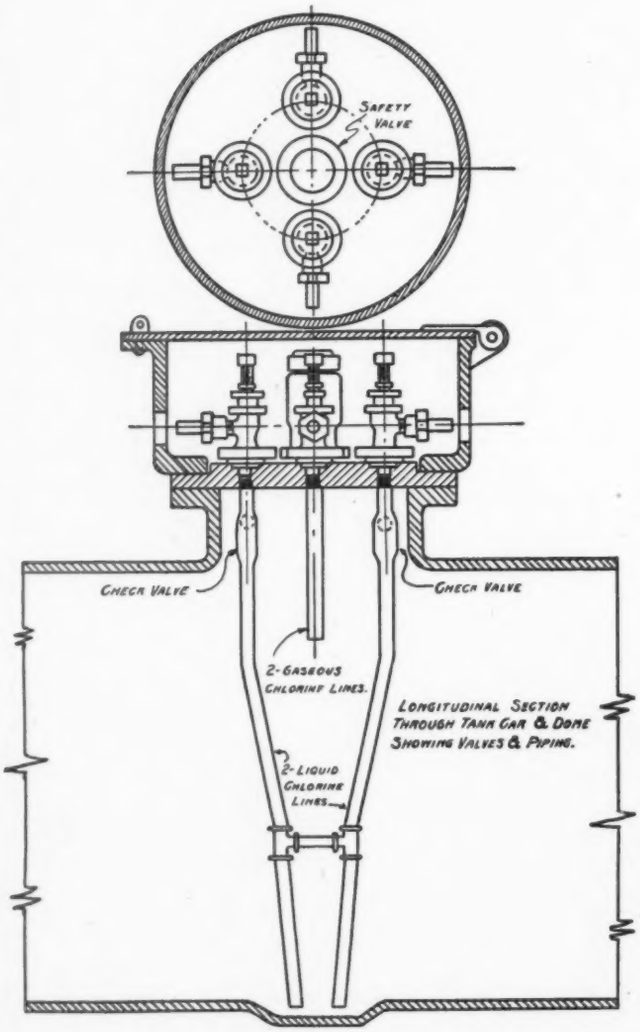
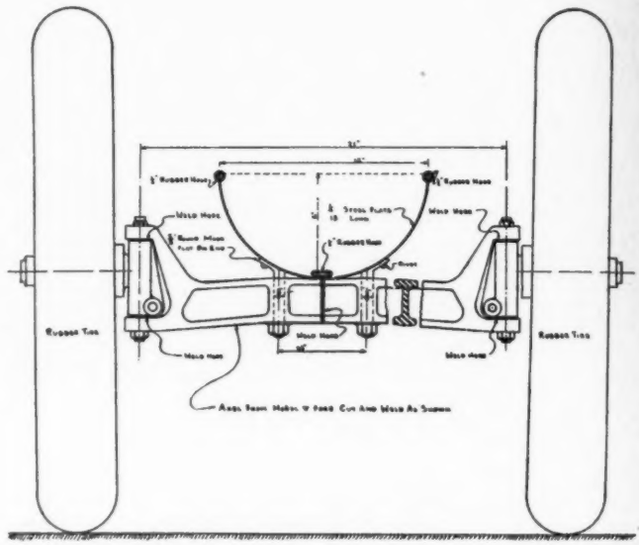


Fig. 17—Details of Dome and Inner Shell of Single Unit Chlorine Tank Car

Safety Cylinder Handling Carriage

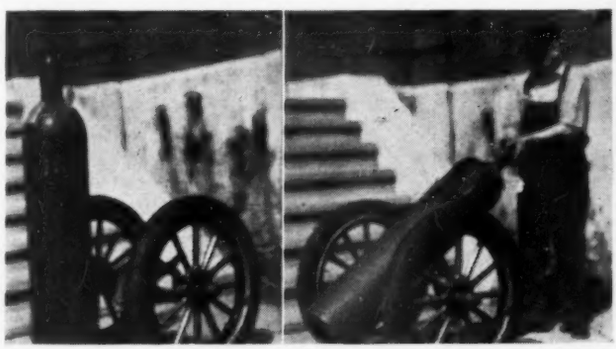
The accompanying pictures and detail sketch illustrate a novel, efficient and inexpensive carriage for transport of cylinders containing chlorine, ammonia or other compressed gases.

The device was designed and constructed from the wheels and front axle of what was once a Model "T" Ford automobile. Its ease of handling is self evident and its use saves many a "weak back" and avoids dangers of injury to the "strong men" around water and sewage plants.



Model "T" Cylinder Carriage
Unique Carriage Designed for Cylinder Handling at the Water Purification Plant of the Philadelphia Suburban Water Co.

To Edward J. Jenkins of the Philadelphia Suburban Water Company, Bryn Mawr, Pa., we are indebted for the illustrations of this unique cylinder truck which was developed in the above plant under his supervision.



In Position *Ready to Ride*

WALLACE & TIERNAN CO., INC.

Manufacturers of Chlorine and Ammonia Control Apparatus
Dry Chemical Feed Devices, etc.
NEWARK, NEW JERSEY

"The Only Safe Water Is a Sterilized Water"

Boston	Chicago	Detroit	Lexington	Omaha	Seattle
Bridgeport	Cleveland	Indianapolis	Los Angeles	Philadelphia	St. Louis
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Charlotte	Dallas	Kansas City	Minneapolis	Roanoke	Washington, D. C.
Chattanooga	Denver	Knoxville	Oklahoma City	San Francisco	

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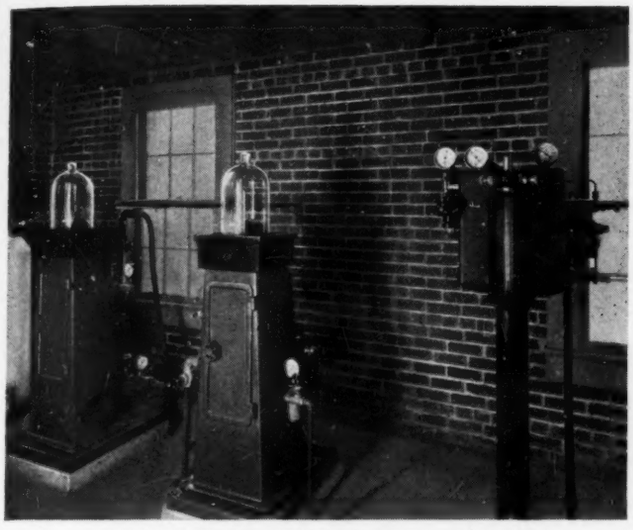
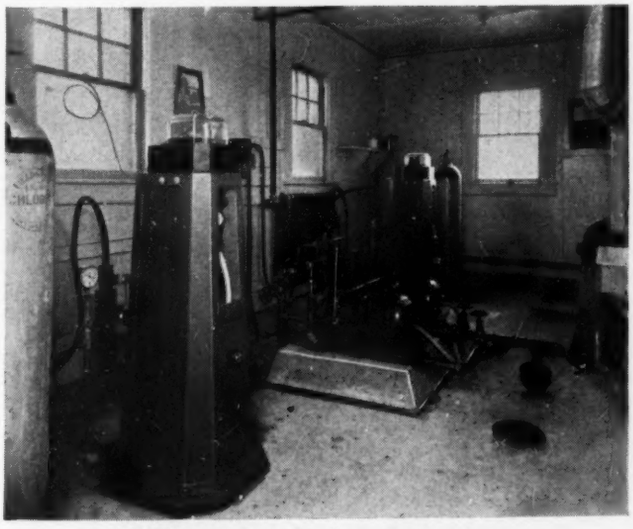


Two Visible Vacuum Chlorinators—1 Manual and 1 Automatic—and Automatic Ammoniator installed at Greenville, S. C.

CHLORINATION

Chlorination is the accepted standard of sterilization in water works practice. Costing only a few cents per million gallons of water treated, easily applied, simply controlled and positive in bactericidal action, it has contributed more than any one other measure in reducing America's typhoid death rate from 30 per 100,000 to less than 3. Whether the source of supply is polluted surface water or clear, sparkling well or spring, its purity should be insured by the certain protection chlorination provides. Over 20,000 units of Wallace & Tiernan equipment in all parts of the world attest the universal accord with which chlorination and W&T Chlorinators are accepted.



Visible Vacuum Control in low capacity equipments —Duplicate "Equiscale" Chlorinators at New London, Conn.

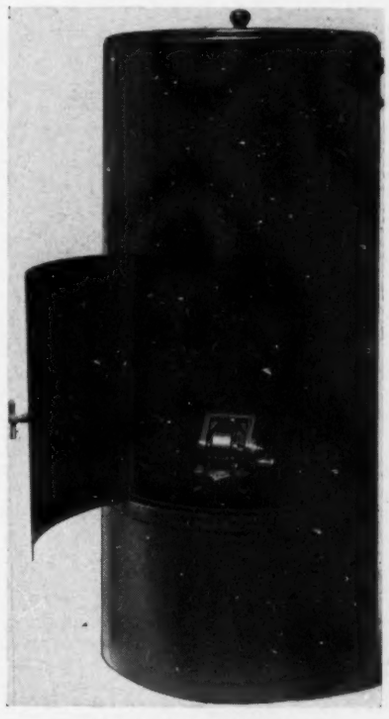
AMMONIATION

The ammonia-chlorine process of water treatment has passed beyond the experimental stage and is accepted as a definite and valued aid in water works operation. Chloramine—formed by the combination of chlorine and ammonia — while somewhat slower in bactericidal action than chlorine offers many distinct advantages. Chloramine residuals persist over long periods and are tasteless and odorless. Chlorophenol and certain organic tastes and odors are prevented.

Chlorinous tastes are eliminated, this being of particular advantage on small gravity water supplies with widely fluctuating flows and with a chlorinator operating at a fixed rate at considerable distance from the town. Aftergrowths in the distribution system are destroyed and algae control made far more efficient owing to the presistent residual being carried through basins, filters and reservoirs. Finally, and most important, a new factor of safety is added by maintaining sterilizing action throughout the distribution system to the consumer's tap, thus eliminating all dangers of subsequent pollution.

APPLICATION OF DRY CHEMICALS

The development of dry chemical application has been of great value in both sanitary and industrial fields. Difficulties from leaking tanks, corroded constant level boxes, clogged orifices, broken valves, and all the untidiness and disagreeable features incident to solution feed systems are eliminated. Of particular advantage in filter plants for applying alum, lime, soda ash or carbon, dry chemical application effects large savings in labor and materials.



Type MOF Dry Chemical Feeder for accurate control of Alum, Lime or Activated Carbon.

W&T EQUIPMENT

Complete in both arrangement and capacity, the W&T line of Chlorinators, Ammoniators and Dry Chemical Feeders is designed to meet every water works requirement. Long life, low maintenance and utmost accuracy and dependability characterize each installation, reinforced by the services of a nationwide organization operating from 29 Sales and Service Headquarters. The recommendation of W&T field representatives involves no obligation. Feel free to call on them.

Current literature on the many phases of chlorination, ammoniation and dry chemical feed is available on request.

SOME PRACTICAL ASPECTS OF HANDLING CHLORINE

By CHRIS F. BINGHAM*

Barberton, O.

There appeared in the September, 1935, issue of the Journal of the American Water Works Association a valuable report, dealing with chlorine, by the Committee on Chemical Hazards in Water Works. This paper is intended to record various practical experiences in chlorine handling and opinions that in their nature had no place in the above committee report. However, the writer will quote freely from the report, where deemed advisable, and recommends that those interested procure a copy of the journal containing it.

Properties of Chlorine

Chlorine gas is approximately two and one-half times as heavy as air at normal temperature and pressure, and hence, leaking chlorine, tends to settle and collect in low places and on the floor of an enclosed room.

Chlorine is neither flammable or explosive. The dry gas does not attack iron, copper, or lead at ordinary room temperature. However, in the presence of moisture it is very corrosive and combines readily with most metals except those classed as the "noble" metals and special alloys. It is important to note that even the dry gas becomes very corrosive at temperatures above 300 degrees F. and is likely to become so at temperatures as low as 195 deg. F.

Chlorine Lines

Rubber and the noble metals are sufficiently resistant to the action of wet chlorine to be satisfactory materials to handle either the moist gas or water solutions. Liquid chlorine in itself cannot, however, be used with hard rubber. During the last year and a half plant tests have been made in Richmond to determine the resistance of asbestos-cement pipe to chlorine solutions. As a result, the prechlorination and copperas-chlorine solution systems have been rebuilt using two and one-half inch "Transite" Class "B" pipe and Class "S" elbows. So far, this installation has given excellent service, the only difficulty encountered was due to its brittleness and the lack of sufficient mechanical support—a few sections of the pipe being broken by strains before adequately supported. The chlorine solution seems to "wet" the inside of the pipe to a depth of ⅛ to 3/16-inch and then stop, no further change was noted in the experimental installation or in the new permanent installation after two months of heavy use.

Extra heavy iron pipe with wrought iron fittings and litharged joints should be used for the chlorine pressure lines. Litharge that has been opened for some time seems to form a carbonate coating on the particles which result in a never-hardening and oily joint compound which will allow the joint to leak probably. Only new litharge is recommended. Care taken in the correct installation of pressure feed lines is a thousand fold repaid. Ammonia valves (of steel) have been used in the chlorine pressure lines at Richmond with satisfactory results, but where possible the standard Chlorine Institute ton container valve has been used because of its convenience, economy and superior construction. In general chlorine needle valves should have either Hastelloy "C" or Monel Metal stems, and joint valve bodies may be constructed of steel, brass or Hastelloy "C."

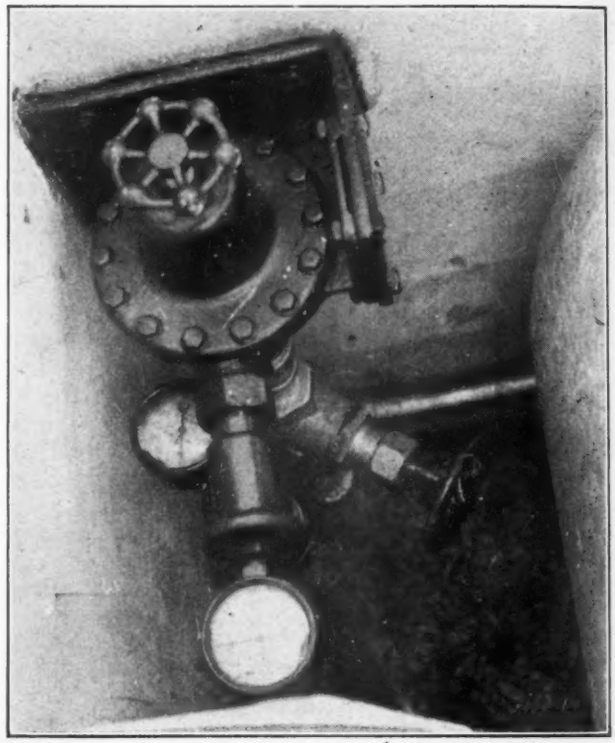
Soft copper tubing connections (cadmium plated) are used in connecting the one-ton chlorine containers to the piping system. We specify that a small wrench "hold" be milled on the bushing on the tubing, to allow holding the tube at the joint during tightening of the coupling. This, to prevent wringing off the tube at that point. The tubing becomes quite hard and rigid after continued service, but its ductility may be renewed by heating slowly to a dull red heat and quenching in water—the customary method of copper softening.

Hard drawn copper fittings and pipe of the "Streamline" type also have been used with essentially *pure* silver as the solder instead of the regular solder, furnished for such pipe, which chlorine attacks. A silver coin will serve as satisfactory solder. High copper content brass fittings have been used with this type of pipe also and seem to work entirely satisfactorily.

Avoiding Condensation Troubles

The gas feed lines should, if possible, always be warmer than the chlorine containers to avoid condensation (re-liquifaction of chlorine) and consequent problems. These lines should also be run on a continuous upgrade from the containers in order that the condensed liquid chlorine will flow back to the containers. Such theoretical conditions cannot always exist practically and, in cases where this is impossible, drip-legs should be provided at every low point on the pipe line—especially so near the chlorinators. Blow-off cocks or other bleeding arrangements are not recommended since they are both dangerous and unnecessary. If the drip legs are so located that the room temperature does not keep the condensate vaporizing at a satisfactory rate, additional heat may be applied by warming with a 100-watt electric bulb permanently installed beneath the leg. The size of the leg varies with the conditions, but it is recommended to be 1¼ times as large as the volume of the pipe line leading from the chlorine container to the leg.

Chlorine reacts with grease and oil to form voluminous frothy substances; with gasoline and other petroleum distillates to form solid complex chlorinated hydro-carbons. Alcohol and ether, even in traces, are converted to solid waxy hexachloroethane. It



One of the Reducing Valves (Looking Down) on the Chlorine Feed Lines. It Is Located on the Manifold Just Beyond the Containers in the Outside Gassing Chamber

is important, therefore, that all grease, moisture, etc., should be thoroughly removed from chlorine lines during their erection. Methane derivatives, chloroform, wood alcohol, and carbon-tetrachloride are the only safe chlorine equipment cleansers to employ.

Whereas, drip legs are very helpful, condensation in chlorine lines should be avoided. If the gas leaving the container drops only a few degrees in temperature it will condense into a liquid in the feed lines and find its way into the chlorinators, with its consequent troubles. This condition can best be avoided by reducing the pressure at the containers to the lowest point permissible for the proper operation of the machines. In fact, if

*Plant Supt., Div. of Filtration, Dept. Public Utilities, Richmond, Va., at time of preparation of this article. Now Tech. Service Engr., Columbia Alkali Corp.

PENNSYLVANIA SALT MFG. COMPANY

WIDENER BLDG., PHILADELPHIA, PA.

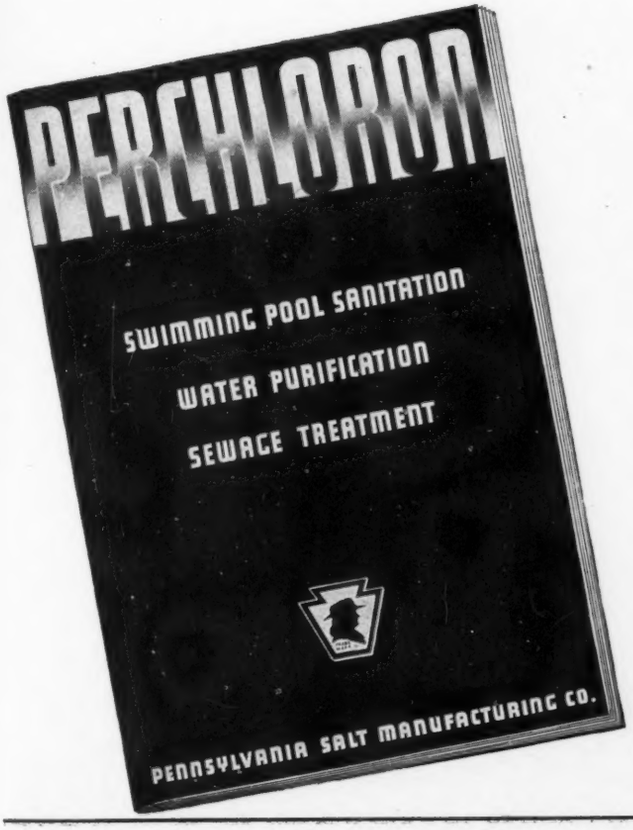
ESTABLISHED 1850

NEW YORK · CHICAGO · ST. LOUIS · PITTSBURGH · TACOMA · WYANDOTTE

PERCHLORON

A convenient concentrated source of chlorine for use in any emergency. Without changing your established procedure, Perchloron makes it possible to safeguard the water supply in case of fire, flood, or other emergency which may cut off normal supplies of liquid chlorine by tying up transportation temporarily.

Perchloron has an available chlorine content of more than 70%. It dissolves readily in water. It is concentrated, stable, and perfectly uniform. Packed 12 handy-sized cans to the case — no return containers to bother you.



In addition to its emergency use, Perchloron is of great value for sterilizing new mains as well as clear wells and filters. It is widely used for swimming pool sanitation. It pays to keep a supply of Perchloron on hand.

Other water purification and sewage treatment products:

LIQUID CHLORINE
AMMONIA
FERRIC CHLORIDE
FILTER ALUM

Handy Light Weight Safety Truck for Cylinder Handling (Courtesy Carl Leipold, Winnetka, Ill.)

the line pressure be kept at 40 pounds per square inch or less no condensation can occur in the lines except at extreme cold temperatures. In Richmond, by keeping the reducing valves (in duplicate) set at 35 pounds per square inch, no liquefaction has resulted, although the chlorine feed lines are 400 feet long and the containers are in compartments outside of the plant which get quite warm in summer and also are artificially warmed in cold weather—an ideal condition for condensation in the feed lines.

Chlorine, in distilled water, at 49.2 deg. F. will form chloral-hydrate, commonly referred to as "chlorine ice." This condition is frequently found in the trays of vacuum type chlorinators during cold weather; but may be overcome by placing an electric light under the tray of the chlorinator. At the same time, reducing the water flow through the tray is also helpful. Since the solubility curve is a very sharp one a rise of only one or two degrees of the water is sufficient to do away with the trouble.

Container Temperatures and Pressures

The per cent of container volume occupied by liquid chlorine in the containers, when loaded to the limit permitted by the Interstate Commerce Commission regulations, is such that at 153.9 deg. F. the cylinder becomes completely filled due to the expansion of the liquid chlorine. Liquids do not have the compressibility or cushioning effect possessed by gases hence any further increase in the temperature will cause enormous pressure in the containers. For this reason, fusible plugs are provided which are intended to soften at slightly above this temperature and thus relieve the dangerous pressure. It is important, therefore, to keep the cylinders below this temperature regardless of the amount of chlorine that they may contain. Experience at the Richmond plant justifies this warning.

There are several practical precautions suggested by the above facts. Cylinders should never be directly heated by flame, steam or even electrical means that can exceed 160 deg. F. To avoid such hazard, warm air from the building is blown through an underground pipe to the containers which are housed in compartments outside of the plant. Secondly, a full cold chlorine cylinder has a lower pressure than one at room temperature; hence, if they are connected together as on a header, the cold cylinder will actually draw in chlorine. If the valve is then closed the overloaded cold cylinder may cause trouble when it becomes warm, even to room temperature. Hence, cylinders should be brought to about the same temperature before being connected together. As another example, the re-loading of containers thought to be empty, is absolutely forbidden unless under technical supervision.

If gas is drawn from a container, the pressure within the container will be reduced. If a constant supply of gas at constant pressure is to be maintained, then heat must be applied to the liquid in the container. The more rapidly the gas is removed, the more rapidly heat must enter. This is usually accomplished by increasing the room temperature. If instead of adding heat, the container is cooled—the pressure falls. This is why a leaking cylinder should be cooled as rapidly as possible. Different opinions exist as to the maximum rate that gas may be drawn from cylinders. Experiments at Richmond have indicated that as much as 800 pounds per day may be drawn from the standard one ton container, in the summer when indoors, with pressure maintained on the gas line at not less than 30 pounds per square inch. However, 400 to 450 pounds per day is about the maximum successful continuous rate of supply from these containers. With the 150 pound cylinder the rate is about 30 pounds per day. Increasing the room temperature and providing air circulation will increase the rate of gassing. Especially so with a full cylinder because there is then a large area of the liquid exposed to the sides of the warmed container. Adequate air circulation is a considerable aid in maintaining sustained gassing rates.

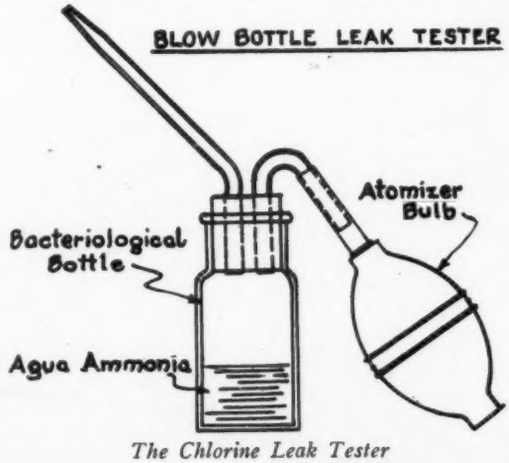
Handling Containers

Containers are built of steel and may be safely handled with care. Dropping or bumping containers is extremely dangerous, and facilities used in handling should be carefully arranged to prevent such rough treatment. Hoisting is to be avoided if possible. Low, rubber tired trucks are preferable if conditions allow. A rubber tired light weight hand-truck for 150 pounds cylinders, first used by Carl Liepold at Winnetka, Ill., plant has proven both safe and convenient. The overhead monorail system used in Richmond for ton containers, involves the use of a lifting hook used to reduce space and suitable for low head operation on such a system. Out of doors storage is provided in racks, the enclosed section being the warmed gassing chamber. The maximum chlorine temperature yet found in these stored containers is 108 deg. F. or a pressure of 160 pounds which is amply safe. In warmer climates it may be well to shield stored containers from direct heat of the sun.

Chlorine may be safely stored indoors. Having the containers in operation mounted near the control machine undoubtedly has its advantages. In small installations, having in storage or in use only a few 150 pound cylinders, this risk is not serious and the practice is to be recommended, but when larger quantities of chlorine are necessary the advantage of the out of door storage and gassing chamber, with only the chlorine feed lines and the machines in the building, is certainly evident.

Ventilation Facilities and Leak Handling

When storage and operating containers are indoors adequate and reliable ventilation is essential. Exhaust air ducts draining



The Chlorine Leak Tester

air from the room should intake at the *floor level* and a fan forcing air into the room should drive the chlorine atmosphere directly out of the building. Where steam is available, a suitably designed ejector system, with discharge to a sewer or stack, is perhaps the best disposition of the escaped chlorine.

The use of neutralization tanks containing caustic, or attempting to stop a leak by spraying water on the leak, or cooling with ice and salt, while theoretically correct, are of doubtful practical value. Practically it has been found at the Richmond plant that the best disposal is by submerging the cylinder, as for example, in the raw water flume, or other convenient large body of flowing water. "Dry Ice" (solid carbon dioxide), is the only method used successfully in cooling a cylinder to stop a leak by sufficiently reducing the gas pressure.

A suitable number of gas masks, of a design approved by the U. S. Bureau of Mines, should be readily available in a convenient location, and all employes should be trained in the correct procedure in putting on the masks. There is quite a prejudice among a large number of operators against the use of a mask in stopping small leaks. Contrary to general statements otherwise, that chlorine exposures produce no cumulative effects, the writer has noted cases of men repeatedly exposing themselves to small concentrations and have ended up with irritations such as results from a heavy concentration. It is well to note that the life of a canister type gas mask of the soda lime-activated charcoal type, depends not only upon the extent to which it is put to active service, but upon the storage conditions. Such canisters deteriorate rather rapidly when left open to the air and, therefore, the bottom opening of the canister should be kept sealed with the plug or disc supplied by the manufacturer. The useful life of a canister cannot be predicted and a fresh canister should always be available. Canisters should be replaced periodically, regardless of use.

Remember three simple rules in using a gas mask:

1. Never use where there is any danger of a deficiency of oxygen.
2. The life of the canister is an unknown quantity.
3. Any gas mask job is a *two man* job.

Even small chlorine leaks are dangerous and should be stopped immediately. A chlorine leak may be readily located by means of aqua ammonia. The best procedure so far found in Richmond consists of the use of a "blow-bottle" here illustrated. This is a bottle of suitable size to carry in one hand conveniently. A rubber atomizer bulb is attached and permits the operator to blow ammonia fumes from the bottle while holding the outlet nozzle near the suspected leak. This outfit can be easily manipulated with one hand.

Flexibility of Chlorinator Service

Chlorine control machines are relatively expensive, yet ample reserve against extra demands or repairs is absolutely essential in every plant. To reduce the number of machines needed, and yet leave reliable reserve at the Richmond plant has been installed a most successful transfer system. Three points of chlorine application before filtration and four control machines are available on the transfer. By means of the transfer system, the opening of a valve permits any or all of the four chlorinators to supply any or all of the three points of application. By changing hose connections two additional control machines may be substituted thus making six machines almost immediately available at any point of chlorine application. Thus six machines give as reliable service as would ordinarily necessitate nine machines.

The author wishes to gratefully acknowledge his indebtedness for the suggestions and criticisms of: M. C. Smith, Chairman of the A. W. W. A. Committee on Chemical Hazards in Water Works; L. H. Enslow, Research Engineer of the Chlorine Institute, and Editor of WATER WORKS AND SEWERAGE, and to Carl Liepold of Winnetka, Ill.

PHILADELPHIA QUARTZ COMPANY

General Offices: 121-129 S. Third St., Philadelphia
Chicago Sales Office: 205 W. Wacker Drive

SILICATES OF SODA FOR WATER TREATMENT

Manufacturing Plants at
ANDERSON, IND. BALTIMORE, MD. CHESTER, PA. BUFFALO, N. Y. KANSAS CITY, KANS. RAHWAY, N. J. ST. LOUIS, MO. UTICA, ILL.

AIDING COAGULATION—Now water supply engineers are improving coagulation with the aid of P.Q. Silicate of Soda. Check over these advantages of the silicate of soda treatment, any one of which would be worth your investigation.

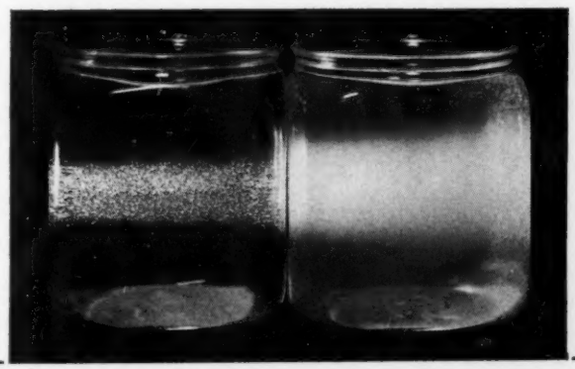
1. Lowered total coagulant cost
2. More rapid and larger floc formation
3. More rapid and more complete settling of floc
4. Longer filter runs
5. Lower turbidity of the filter effluent
6. Lower color in the filter effluent

Several methods of application are being used. The correct one depends on the type of water, the equipment available, the operating procedure used and the improvement desired. Ask for further information about making jar tests for comparison with your present practice.

TREATMENT FOR CORROSION—Many waters are corrosive. The addition of small amounts of sodium silicates will prevent corrosion. Municipalities treating for corrosion with silicate of soda find that this method is less expensive because it requires less supervision. May we give you the details?

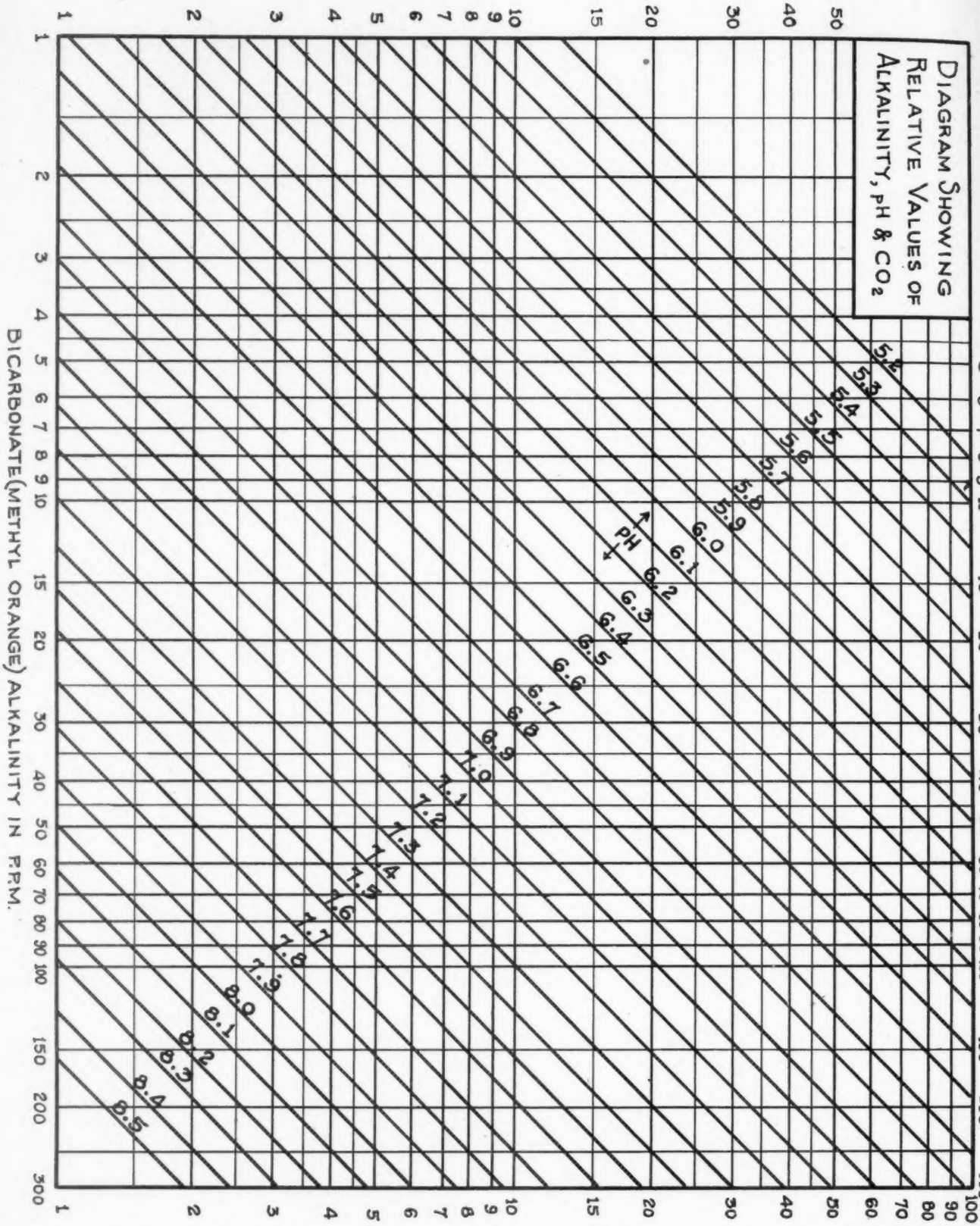
* * *

The experience of water works engineers in using P.Q. Silicate for treating water covers a period of time. With this background, our Technical Department will be glad to discuss your problems.



Raw untreated water, with same quantity alum added to both jars. Left: silicate treated. Right, without silicate. Photographed five minutes after stirring of chemicals ceased.

Conversion Chart—pH, Alkalinity, Carbon Dioxide


FREE CARBON DIOXIDE IN P.P.M.
BICARBONATE (METHYL ORANGE) ALKALINITY IN P.P.M.
Diagram Showing Relative Values of Alkalinity, pH & CO_2
pH

NOTE: *This chart has an especial usefulness in determining free carbon-dioxide content of waters without making the tedious and frequently inaccurate CO_2 titration. Alkalinity and pH readings are more easily and accurately made. To find CO_2 content —Locate pH value diagonal; follow it to intersection with alkalinity value vertical. The horizontal line passing through this same point reveals the correct free CO_2 content. (This chart was supplied by Nicholas S. Hill Associates, New York City.*

AREAS OF CIRCLES—SQUARES—SQUARE ROOTS

(Also Fractions to Decimal Equivalent.)

—Number— Fraction	Decimal	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
1/16	.0625	.0039	.2500	.0031
1/8	.125	.0156	.3536	.0125
3/16	.1875	.0352	.4330	.0276
1/4	.25	.0625	.5000	.0491
5/16	.3125	.0977	.5590	.0767
3/8	.375	.1406	.6124	.1105
7/16	.4375	.1914	.6614	.1503
1/2	.50	.2500	.7071	.1964
9/16	.5625	.3164	.7500	.2485
5/8	.625	.3906	.7906	.3068
11/16	.6875	.4727	.8297	.3712
3/4	.75	.5625	.8660	.4418
13/16	.8125	.6602	.9014	.5185
7/8	.875	.7656	.9354	.6013
15/16	.9375	.8789	.9683	.6903
1	1.	1.000	1.000	.7854
1 1/8	1.125	1.266	1.061	.9940
1 1/4	1.25	1.563	1.118	1.227
1 3/8	1.375	1.891	1.175	1.485
1 1/2	1.50	2.250	1.225	1.767
1 5/8	1.625	2.641	1.275	2.074
1 3/4	1.75	3.063	1.323	2.405
1 7/8	1.875	3.516	1.369	2.761
2	2.	4.000	1.414	3.142
2 1/8	2.125	4.516	1.458	3.547
2 1/4	2.25	5.063	1.500	3.976
2 3/8	2.375	5.641	1.541	4.430
2 1/2	2.50	6.250	1.581	4.909
2 5/8	2.625	6.891	1.620	5.412
2 3/4	2.75	7.563	1.658	5.940
2 7/8	2.875	8.266	1.696	6.492
3	3.	9.000	1.732	7.069
3 1/8	3.125	9.766	1.768	7.670
3 1/4	3.25	10.56	1.803	8.296
3 3/8	3.375	11.39	1.837	8.946
3 1/2	3.50	12.25	1.871	9.621
3 5/8	3.625	13.14	1.904	10.32
3 3/4	3.75	14.06	1.937	11.04
3 7/8	3.875	15.02	1.969	11.79
4	4.	16.00	2.000	12.57
4 1/8	4.125	17.02	2.031	13.36
4 1/4	4.25	18.06	2.062	14.19
4 3/8	4.375	19.14	2.092	15.03
4 1/2	4.50	20.25	2.121	15.90
4 5/8	4.625	21.39	2.151	16.80
4 3/4	4.73	22.56	2.180	17.72
4 7/8	4.875	23.77	2.208	18.67
5	5.00	25.00	2.236	19.64
5 1/4	5.25	27.56	2.291	21.65
5 1/2	5.50	30.25	2.345	23.76
5 3/4	5.75	33.06	2.398	25.97
6	6.	36.00	2.450	28.27
6 1/4	6.25	39.06	2.500	30.68
6 1/2	6.50	42.25	2.550	33.18
6 3/4	6.75	45.56	2.598	35.78
7	7.	49.00	2.646	38.48
7 1/4	7.25	52.56	2.693	41.28
7 1/2	7.50	56.25	2.739	44.18
7 3/4	7.75	60.06	2.784	47.17
8	8.00	64.00	2.828	50.27
8 1/4	8.25	68.06	2.872	53.46
8 1/2	8.50	72.25	2.916	56.75
8 3/4	8.75	76.56	2.958	60.13
9	9.00	81.00	3.000	63.62
9 1/4	9.25	85.56	3.041	67.20
9 1/2	9.50	90.25	3.082	70.88
9 3/4	9.75	95.06	3.123	74.66
10	10.0	100	3.162	95.03
..	....	....	....	....
..	....	....	....	....
10	....	100	3.162	78.54
11	....	121	3.317	95.03
12	....	144	3.464	113.1
13	....	169	3.606	132.7
14	....	196	3.742	153.9
15	....	225	3.873	176.7
16	....	256	4.000	201.1
17	....	289	4.123	227.0
18	....	324	4.243	254.5
19	....	361	4.359	283.5
20	....	400	4.472	314.2
21	....	441	4.583	346.4
22	....	484	4.690	380.1
23	....	529	4.796	415.5
24	....	576	4.899	452.4
25	....	625	5.000	490.9
26	....	676	5.099	530.9
27	....	729	5.196	572.6
28	....	784	5.292	615.8
29	....	841	5.385	660.5
30	....	900	5.477	706.9
..	....	...	....	....
..	....	...	....	....

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
31	961	5.568	754.8
32	1024	5.657	804.2
33	1089	5.745	855.3
34	1156	5.831	907.9
35	1225	5.916	962.1
36	1296	6.000	1017.9
37	1369	6.083	1075.2
38	1444	6.164	1134.1
39	1521	6.245	1194.6
40	1600	6.325	1256.7
41	1681	6.403	1320.3
42	1764	6.481	1385.4
43	1849	6.557	1452.2
44	1936	6.633	1520.5
45	2025	6.708	1590.4
46	2116	6.782	1661.9
47	2209	6.856	1734.9
48	2304	6.928	1809.6
49	2401	7.000	1885.7
50	2500	7.071	1936.5
51	2601	7.141	2042.8
52	2704	7.211	2123.7
53	2809	7.280	2206.2
54	2916	7.349	2290.2
55	3025	7.416	2375.8
56	3136	7.483	2463.0
57	3249	7.500	2551.8
58	3364	7.616	2642.1
59	3481	7.681	2734.0
60	3600	7.746	2827.4
61	3721	7.810	2922.5
62	3844	7.874	3019.1
63	3969	7.937	3117.2
64	4096	8.000	3217.0
65	4225	8.062	3318.3
66	4356	8.124	3421.2
67	4489	8.185	3525.7
68	4624	8.246	3631.7
69	4761	8.307	3739.3
70	4900	8.367	3848.5
71	5041	8.426	3959.2
72	5184	8.485	4071.5
73	5329	8.544	4185.4
74	5476	8.602	4300.8
75	5625	8.660	4417.9
76	5776	8.718	4536.5
77	5929	8.775	4656.6
78	6084	8.832	4778.4
79	6241	8.888	4901.7
80	6400	8.944	5026.5
81	6561	9.000	5153.0
82	6724	9.055	5281.0
83	6889	9.110	5410.6
84	7056	9.165	5541.8
85	7225	9.220	5674.5
86	7396	9.274	5808.8
87	7569	9.327	5944.7
88	7744	9.381	6082.1
89	7921	9.434	6221.1
90	8100	9.487	6361.7
91	8281	9.539	6503.9
92	8464	9.592	6647.6
93	8649	9.644	6792.9
94	8836	9.695	6939.8
95	9025	9.747	7088.2
96	9216	9.798	7238.2
97	9409	9.849	7389.8
98	9604	9.900	7543.0
99	9801	9.950	7697.7
100	10000	10.00	7854.0
101	10201	10.05	8011.9
102	10404	10.10	8171.3
103	10609	10.15	8332.3
104	10816	10.20	8494.9
105	11025	10.25	8659.0
106	11236	10.30	8824.7
107	11449	10.34	8992.0
108	11664	10.39	9160.9
109	11881	10.44	9331.3
110	12100	10.49	9503.3
111	12321	10.54	9676.9
112	12544	10.58	9852.0
113	12769	10.63	10029
114	12996	10.68	10207
115	13225	10.72	10387
116	13456	10.77	10568
117	13689	10.82	10751
118	13924	10.86	10936
119	14161	10.91	11122
120	14400	10.95	11310
121	14641	11.00	11499
122	14884	11.05	11690
123	15129	11.09	11882
124	15376	11.14	12076
125	15625	11.18	12272
126	15876	11.23	12469
127	16129	11.27	12668
128	16384	11.31	12868
129	16641	11.36	13070
130	16900	11.40	13273
131	17161	11.45	13478
132	17424	11.49	13685
133	17689	11.53	13893
134	17956	11.58	14103
135	18225	11.62	14314
136	18496	11.66	14527
137	18769	11.70	14741
138	19044	11.75	14957
139	19321	11.79	15175
140	19600	11.83	15394
141	19881	11.87	15615
142	20164	11.92	15837
143	20449	11.96	16061
144	20736	12.00	16286
145	21025	12.04	16583
146	21316	12.08	16742
147	21609	12.12	16972
148	21904	12.17	17203
149	22201	12.22	17437
150	22500	12.25	17671
151	22801	12.29	17908
152	23104	12.33	18146
153	23409	12.37	18385
154	23716	12.41	18627
155	24025	12.45	18869
156	24336	12.49	19113
157	24649	12.53	19359
158	24964	12.57	19607
159	25281	12.61	19856
160	25600	12.65	20106
161	25921	12.69	20358
162	26244	12.73	20613
163	26569	12.77	20867
164	26896	12.81	21124
165	27225	12.85	21382
166	27556	12.88	21642
167	27889	12.92	21904
168	28224	12.96	22168
169	28561	13.00	22432
170	28900	13.04	22698
171	29241	13.08	22966
172	29584	13.11	23235
173	29929	13.15	23506
174	30276	13.19	23779
175	30625	13.23	24053
176	30976	13.27	24328
177	31329	13.30	24606
178	31684	13.34	24885
179	32041	13.38	25165
180	32400	13.42	25447
181	32761	13.45	25730
182	33124	13.49	26016
183	33489	13.53	26302
184	33856	13.56	26590
185	34225	13.60	26880
186	34596	13.64	27172
187	34969	13.67	27465
188	35344	13.71	27759
189	35721	13.75	28055
190	36100	13.78	28353
191	36481	13.82	28652
192	36864	13.86	28953
193	37249	13.89	29255
194	37636	13.93	29559
195	38025	13.96	29865
196	38416	14.00	30172
197	38809	14.04	30481
198	39204	14.07	30791
199	39601	14.11	31103
200	40000	14.14	31416
...	.....	....	.....
...	.....	....	.....
...	.....	....	.....
...	.....	....	.....
...	.....	....	.....

SEWERAGE

Whereas, this section is devoted almost exclusively to Sewerage, it was not possible to segregate material, which pertains to Water as well as Sewage, except at the expense of duplication.

The Water Works Section will be found to contain considerable material of direct bearing on Sewerage. Such, for example, are "Main Line Metering"; "The Parshall Flume"; "Pumps and Pumping"; Elemination of Check Valve Slam"; Practical Hydraulics"; "Practical Electricity in the Plant"; "Chlorine and its Safe Handling," et. al.

MAINTAINING A SEWERAGE SYSTEM

By GEORGE E. FINCK

Engineer, Bureau of Sewers, Baltimore, Md.

The extent of maintenance required to keep a sewerage system in successful operation may be traced more or less to the following causes: (1) Poor Design and Construction; (2) Depreciation and Misuse.

The amount of maintenance necessary on account of depreciation due to wear and tear is usually not great, particularly if the system is new, and of good workmanship and material. A frequent source of trouble, however, if not guarded against will result from the tapping of sewers for extension of house connections. No sewer in the City of Baltimore is permitted to be tapped unless a permit from this Bureau has been issued, and the *work must be done under the supervision of a Department Inspector* and by a qualified pipe layer. Noisy and broken manhole covers add a great deal to general maintenance work and numerous inlet heads have to be repaired and replaced from time to time, all of which is the result of increased traffic.

Dealing With the Root Problem

To have low maintenance costs, good construction is essential under careful and competent inspectors. A very important factor in this respect is the making of tight joints for the exclusion of ground water and to guard against the entrance of tree roots. Numerous chokages in the sanitary sewers of Baltimore are due to the roots of poplar and willow trees. The roots of oak and similar shade trees do not seem to give any trouble. In each case where the sewer becomes chocked because of tree roots, and it is necessary to uncover the sewer, the joints through which the roots have passed are made over with great care in the following manner. A ring of jute is inserted in the bell of the pipe the same as when the usual Portland cement joint is made. Then puddle clay, to which has been added a liberal quantity of coarse salt is packed over the jute to within one-half inch of the end of the bell. On top of this is placed a mortar of cement and sand. This type of joint has proved very effective against the entrance of tree roots. The planting of poplar trees on public highways of the city of Baltimore is now prohibited.

The misuse of the sanitary sewerage system is probably the principal contributing factor to high maintenance costs. Although sewers are intended for definite purposes, they often are used as a means of disposing of materials intended for the rubbish pile. The following are but a few of the objects which have been taken from Baltimore sewers from time to time: Bricks, flat irons, dish pans, broom handles, bottles, garden hose and occasionally small dead animals. The only conceivable means by which such objects can be introduced into the sewers is by the unauthorized removal of manhole covers and through sewer cleanouts on the plumbing lines.

The amount of maintenance required for the storm drainage system can be held to a minimum if streets are frequently cleaned and the debris removed before it is washed into the drains, where it usually has to be removed at considerable cost. Present day heavy traffic has brought about the necessity for prompt removal of snow. The practice generally followed is to dispose of it into the storm drainage system. It is usually mixed with debris and after the snow has melted in the drains this debris remains behind and has to be removed. It is essential that only large drains should be used for snow removal and great quantities of water used for flushing purposes.

[NOTE—In the magazine section of this issue appears another article on "Sewer Maintenance Practices" by John H. Brooks, Jr., Supt. of Sewerage, Worcester, Mass.]

Solution of the Oil Dumping Problem

A serious problem confronting engineers in charge of sewerage systems relates to the disposal of gasoline and oil from automobile crank cases into the storm drains. Many cities have had serious explosions as the result of this practice. The City of Baltimore has to a great extent overcome the problem by the passing of an ordinance requiring that waste oils, greases, crank case drainings and similar products be stored on the premises in tight steel containers. The material is then collected and disposed of periodically under direct control of City authorities. This arrangement has proved satisfactory because it provides garages and similar establishments with a way of disposing of oils and greases, as the City has previously found it almost impossible to police all garages to enforce an existing ordinance which prohibited the discharge of oil and gasoline into the sewers. [A copy of the Baltimore ordinance, covering oil disposed, can be had by addressing the author.—Editor.]

It has been found that the large storm drains require little if any cleaning as they are usually well flushed at every heavy rain. Inlets require periodic cleaning to remove decomposing material and an occasional dead animal. Disinfectants and deodorants are used at times when odors are detected in the inlets.

The principal source of trouble in a sewerage system is usually confined to the smaller sizes, namely 8 inches and 10 inches in diameter. When the larger sewers need cleaning it is usually due to wastes from industrial plants.

Tools and Equipment

The proper selection of cleaning tools plays an important part in helping to decrease maintenance costs. There are two types of cleaning rods in use in Baltimore. Jumbo rods No. 10 used to clean out storm water drains are of wood, 3 ft. in length and about 2 inches thick. They have strength and are light enough to float on the water while being forced through the drain. Other rods used to clean sanitary sewers are 4 ft. long and are 1⅞x1⅞ inches in cross section. Other tools such as scoops, root cutters, etc., are essential. Flexible steel cables with steel rollers at the end are used to clean house sewers.

Flexible Sewer Rods

A new type of equipment has recently been purchased for removing obstructions in main line sewers. It consists of 3 ft. flexible steel rods which can be coupled together with connectors especially designed for the insertion of a proper tool for twisting purposes. The flexible sectional-rod cable, thus made up, is run through a 1½-in. pipe guide rigidly fastened in a vertical position in a manhole, the lower end of which guide points to and partly enters the pipe of the sewer. This provides a guide for the flexible rod cable on the end of which is a suitable boring tool of the cork screw or auger type. The boring tool and cable is advanced forward in the sewer by hand pressure and by means of a twisting action accomplished by a turning tool inserted in the connector. When the obstruction is reached the boring tool thus takes a "bite" into the material, a portion of which can be removed by pulling or jerking the cable back a short distance. The procedure is followed until the entire obstruction is bored out and removed.

The advantage of such equipment lies in the fact that it can be operated from the street surface, whether the manhole is full of water or empty. Being flexible it is peculiarly fitted for sewers having bends and short turns and for the further reason that it can be operated effectively from manholes which are either deep or shallow.

Maintenance Practice

The following is the organization and practice adopted for maintaining more than 1,900 miles of sewers and drains in Baltimore: For the cleaning of inlets and manholes there is maintained a group of approximately 15 men divided into 5 small groups. Each group is equipped with a truck and assigned to a particular territory. A daily record is kept of their activities with the result that each inlet and manhole throughout the city receives attention at periodic intervals. Approximately twelve to fifteen hundred inlets are thus cleaned per week. A group of 20 men with four trucks is constantly employed in maintaining house connections and small lateral sewers, and a third group of 6 men and truck maintains the larger sized sewers and drains. By this method the City's sewers are kept under continuous maintenance, thereby reducing complaints, and eliminating inconvenience to property owners as much as possible. The Department maintains a complaint Division where complaints are received during office hours and arrangements are made to receive calls and render service until midnight. All complaints received during these hours are immediately transmitted to the various maintenance foremen for prompt attention.

No force is maintained after midnight as the number of complaints does not justify it, although in cases of storms and other emergencies we have an arrangement whereby the foremen and laborers can be communicated with promptly and detailed to the work.

Complaint Handling

When a complaint from a property owner is received that water is backing up through the sanitary fixtures, the complainant is advised to obtain the services of a registered plumber in order to determine whether the chokage is confined to the premises or is beyond the limits of private property. The reason for this is that the City of Baltimore maintains the main line sewers, and such portions of the house connection as are laid in public thoroughfares. By this policy expense to the city of investigating private property complaints is reduced to a minimum. Property owners are charged with the cost of removing chokages from sanitary house connections only, when the nature of the chokages indicates a misuse of the sewer. All main line chokages, and chokages in house connections resulting from tree roots, are cleared at city expense.

SEWER CLEANING WITH RUBBER BEACH BALLS

By A. M. RAWN, C.E.*

Los Angeles, Calif.

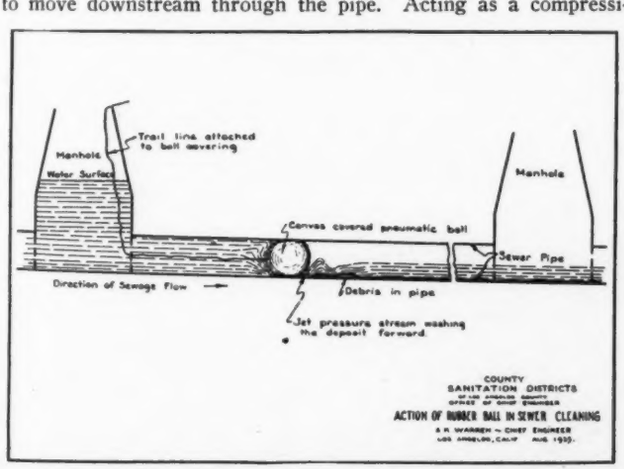
During construction of the sewer lines of the Los Angeles County Sanitation Districts, the problem of cleaning sand and debris from newly constructed lines gave rise to the trial of pneumatic rubber beach balls for this purpose. The use of beach balls was the outgrowth of the usual trial and error methods of using pull through devices, sluicing, use of fire hose and the like.

What is termed a beach ball in this narrative is the ordinary type of commercial pneumatic rubber ball commonly used at play grounds, at beach resorts and otherwise. The rubber is thin and the ball can be blown up to varying degrees of inflation at will. As furnished commercially, the balls have no covering and consist simply of elastic rubber. These balls are manufactured in sizes (diameters) of 6 to 30 inch diameter when fully inflated.

Procedure

For use in cleaning sewers the ball is first inflated and then wrapped in a covering of canvas or burlap, the edges of which are sewed together. A trail-line a little longer than the distance between manholes is then attached securely to the covering. The size of the ball and its covering should be such as to fit fairly snugly into the sewer leaving the downstream side of the manhole.

Immediately the ball is kicked into the pipe, sewage commences to back up in the manhole and continues to increase in depth until such time as its pressure is great enough to force water *under* the ball. (See sketch.) The ball then commences to move downstream through the pipe. Acting as a compressible floating plug it affords enough obstruction so that a continuous high velocity jet spurts under and to some extent around the balls, thereby sluicing all movable material ahead to the next manhole.



Sketch Showing Action of Beach Ball During Sewer Cleaning

Should the ball encounter an obstruction which is immovable (for instance a joint fin or the like), it merely indents to the necessary degree and moves forward. About the only fixed obstruction which will stop the forward progress of the ball is a root mass or some similar obstruction tightly wedged into the pipe. Brick, stones, bottles, loose metal parts, broken pieces of pipe, sand, gravel and settled sludge are easily moved ahead.

If the ball stops momentarily, a pull on the trail-line is usually sufficient to set it again in motion and if the pipe is quite dirty the trail-line can be snubbed to a step in the upper manhole and the ball's progress retarded to the required degree as the lower manhole is approached, thus giving time for complete removal of accumulated debris which the sewage has piled up ahead of the ball.

Much time may be saved by conserving the sewage pressure-head as the ball floats into the lower manhole. Just as the ball comes into view at the lower manhole, the snubbed trail-line is cast off and as the ball floats into the lower manhole with the gush of sewage, it is immediately kicked into the lower (outlet) pipe. The trail-line is picked up by fishing for it and the work proceeds as before.

In ordinarily dirty lines three men are employed as a crew and have cleaned in excess of four miles of sewer pipe in an eight hour working day.

The canvas covering serves two purposes: it permits ready attachment of the trail-line and also affords a measure of protection against puncture by razor blades, glass and sharp metal particles in the sewage sediment. The operation and maintenance crew carry along inner tube vulcanizing patches and small holes in balls are readily repaired on the job without much loss of time.

A Real Test

As a measure of the utility of this method of cleaning, one outstanding example will be noted. A 24-inch diameter reinforced concrete pipe inverted siphon carries the sewage of one main under the Los Angeles River flood control channel. The siphon is about 800 feet in length. A ball, with trail-line attached, was inserted in the upstream end of the pipe; and, although, it took thirty-six hours to work its way through, there appeared ahead of it about a truck load of sand, gravel, bricks and boulders as well as a half-dozen flash boards which had dropped into the sewer at the upstream gate. The ball was put through again immediately and appeared at the outlets in less than an hour.

*Asst. Chief Engr., Los Angeles County Sanitation District, Los Angeles.

SOME SEWERAGE OPERATING KINKS*

By A. M. RAWN[1]

Associate Editor

Sewer cleaning operations on a large trunk sewer system give rise to many notions and ideas regarding best methods. If given the opportunity, an intelligent operation and maintenance crew will probably develop that method which best suits the system upon which they are working. In time they will iron out difficulties incidental to their equipment and eventually may evolve something useful to their brethren elsewhere. In the hope that they have done the latter, the writer presents a few operation and maintenance "kinks" which have been evolved entirely by the field operation forces on the Los Angeles County Sanitation Districts' system. Nothing new is claimed for the ideas and many an operation man may recognize in each, or all, a counterpart of what he daily practices.

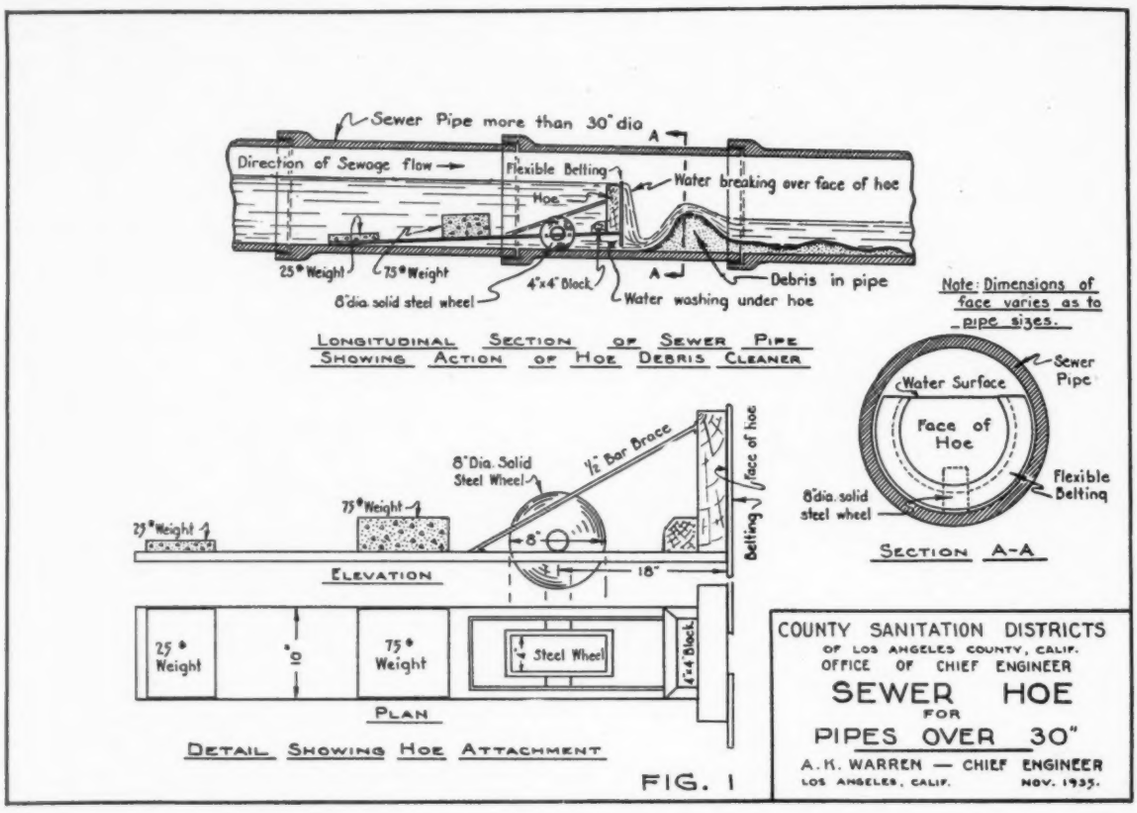


Fig. 1.—The Sewer "Hoe" for Cleaning Sewers Larger Than 30 In. Diameter.

Sewer Cleaning

The writer in the October, 1935, issue of WATER WORKS AND SEWERAGE described the use of rubber beach balls for cleaning lines up to 30 inches in diameter. Above 30 inches the balls are expensive and hard to obtain so that for cleaning circular sewers larger than 30 inches in diameter the district forces use a form of "hoe" shown as Fig. 1. It is simply and easily made and can be assembled in the ordinary manhole without much trouble.

In operation the "hoe" is assembled in the manhole and the proper sized flexible belting is attached to its downstream face. Belting is cut and fitted for each size of pipe from 30 inches to 60 inches for circular pipe, and is properly stiffened with sheet metal as is required in the larger sizes. With the exception of the belting attached to the face of the "hoe," the same equipment is used for cleaning all sizes from 30 to 60 inch pipe lines.

Following its assembly in the manhole, the "hoe" is thrust into the downstream pipe and the trail line is attached to the tail board the belting will have to flex forward to permit the escape of water collected behind the "hoe" face. If this precaution is taken, and the tail board is suitably weighted, one may be assured that just about anything movable below the backed-up water line will be shoved or sluiced ahead to the next manhole. Like the pneumatic

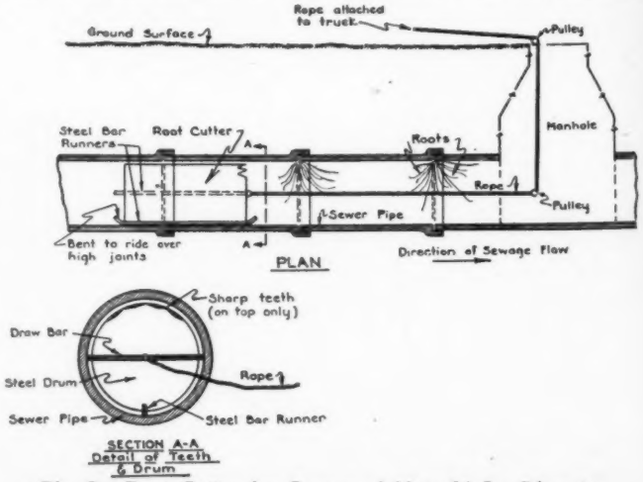


Fig. 2.—Root Cutter for Sewers of 12 to 36 In. Diameter.

*From WATER WORKS AND SEWERAGE, May, 1936.

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CHICAGO PUMP COMPANY

2349 Wolfram St., CHICAGO, ILLINOIS

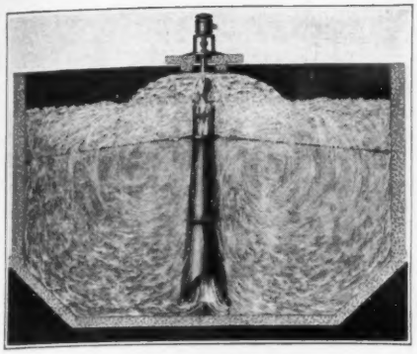
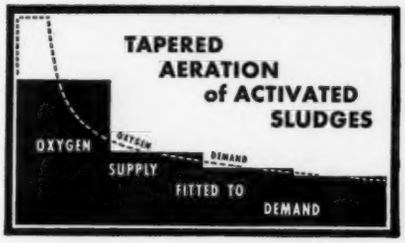


Fig. 2312—Mechanical Aerator
Flora, Ill., installation giving 98% reduction of domestic sewage of 570 p.p.m., 24-hr. average (5-day) B.O.D. Power consumption of 0.337 Kilowatt hours per lb. B.O.D. reduced, measured on primary effluent of 330 p.p.m. B.O.D. Ask for Bulletin 128-L.
Chicago Pump Co. also manufactures the Combination Aerator - Clarifier which performs straight aeration and clarification simultaneously in a single tank. Ask for Bulletin 128-K.



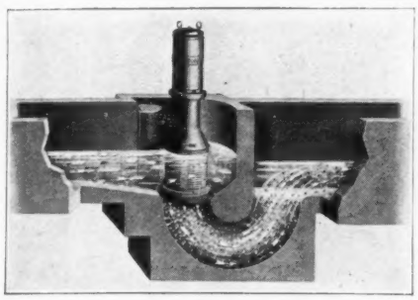
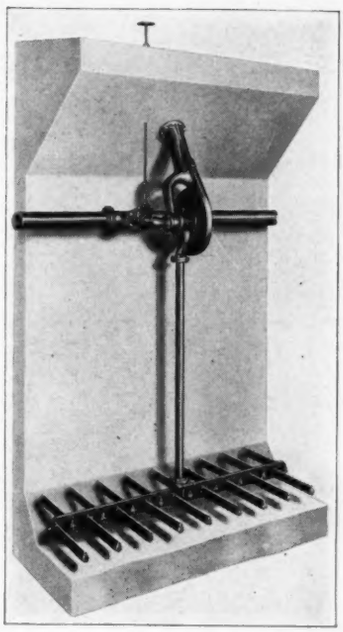
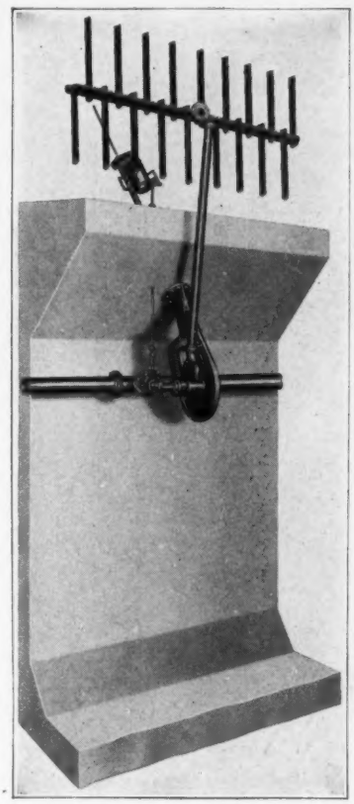


Fig. 2202—Comminutor
Eliminates screenings and screenings disposal. Prevents odors and flies. Cuts coarse sewage matter into small settleable solids without removal from the channel.





Figs. 2905 (left) and 2910 (right)—Swing Diffusers
Controlled aeration for the Activated Sludge Process. Diffuser tube assembly can be raised to tank walk. Simple regulation of air supply from tank walk. Tube cleaning without dewatering tanks or interrupting operation.

Fig. 1731-1—Vertical Open-shaft Non-Clog Pump
Universal Flexible Couplings in shaft compensate for misalignment. Ask for Bulletin 126.

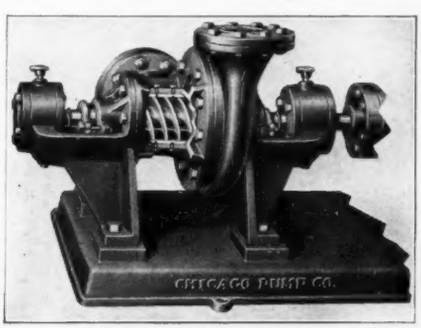


Fig. 1860—Scru-Peller Primary Sludge Pump
Screw conveyor in the suction ahead of the impeller. Stellited cutters prevent clogging. The capacity can be varied instantly. Ask for Bulletin 128-D.

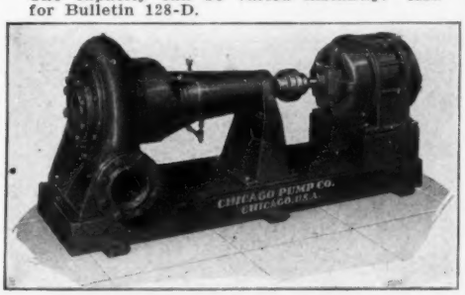


Fig. 1774—Horizontal Non-Clog Pump
Being mounted directly on base prevents pump being pulled out of alignment by long lines of piping. Ask for Bulletin 127.

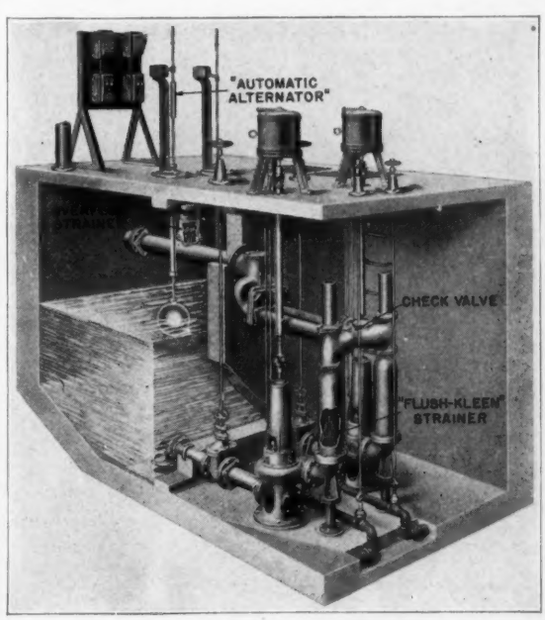


Fig. 2038—Flush-Kleen Sewage Pumping Station
Requires no attention. NEVER CLOGS. Automatically backwashes strainer. Keeps solids from basin and pumps. Impeller handles water, only. Coarse sewage matter is stopped by Flush-Kleen strainer and is flushed out through discharge pipe. Check valve prevents discharging back through inlet line. Ask for Bulletin 122.

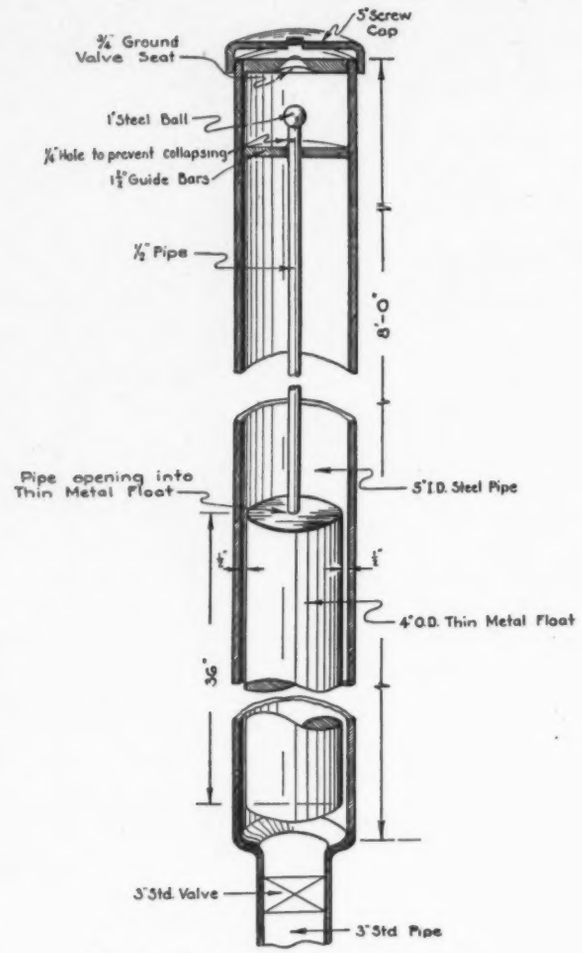


Fig. 3.—Air Relief Valve for Force Main.

cleaning ball, described in the October, 1935, issue of WATER WORKS AND SEWERAGE, the "hoe" moves easily over fixed obstructions.

Root Cutting

Many types of root cutters have been manufactured and sold. A number have been tried on the districts' lines. None of them, however, has proven much more efficient than the simple, inexpensive device shown herein as Fig. 2. It is simply and easily made of ordinary butt-welded steel pipe of commercial sizes.

To make it, take a piece of pipe about 18 inches long, serrate and sharpen the edges of both ends, and weld four shoes to the outside of the pipe. Affix halters for the pull and trail lines—and the job is done.

For an 8-inch line job use a 6-inch diameter pipe and ¼-inch strap runners or shoes. For a 12-inch line, use 10-inch pipe. A 12-inch diameter pipe is large enough for a 15-inch line, and so on. The sharpened notches in the pipe ends should be rather deep and wide so that they may pinch and hold the root, tearing or cutting it loose at its point of entrance into the line at which point it is usually quite small and relatively weak.

The pull line is thrust or pulled through with sewer rods, if it cannot be floated through the line. Pulley-blocks are then suitably arranged at the downstream manhole so that pulling may be done with the maintenance truck.

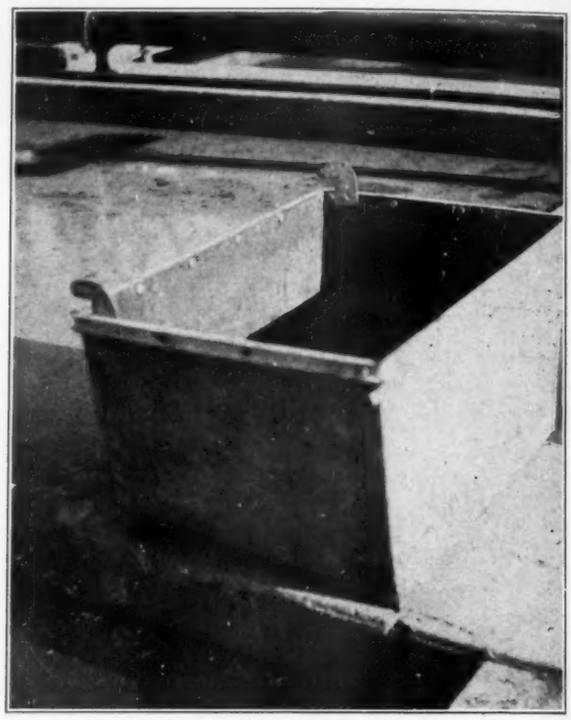
Lacking the proper diameter pipe for an operation, the operation and maintenance crew once manufactured a similar root cutter from a discarded water tank salvaged from a dump heap. It is still used upon occasion.

Air-Relief Valve

Figure 3 illustrates a type of air relief valve used in the 3½ mile (36-inch diam.) effluent pump line leading from the districts' sewage treatment plant. The valve pictured is installed at a summit in the line about 2,000 feet from the plant where air must be tapped off if the line is to operate efficiently. It is also important that none of the effluent escapes through the blow-off.

A number of valves were tried but all operated with indifferent success until that sketched was installed. As may be seen, it consists of a simple float operating a steel ball valve attached to the end of a section of ½-inch pipe. The ball seats in a ground valve seat tapered to catch and center the ball as it rises. The valve case is constructed from a 5-inch diameter, butt-welded, steel pipe.

The secret of the mechanism is the small hole drilled in the ½-inch pipe near the ball. This is to permit admission of air into the light metal float, equalizing the pressures inside and out on the float and preventing collapse of the thin metal cylinder. When first constructed the hole was omitted and the float promptly collapsed, rendering the valve ineffective. When rebuilt, the air inlet hole was drilled and the valve, operating about



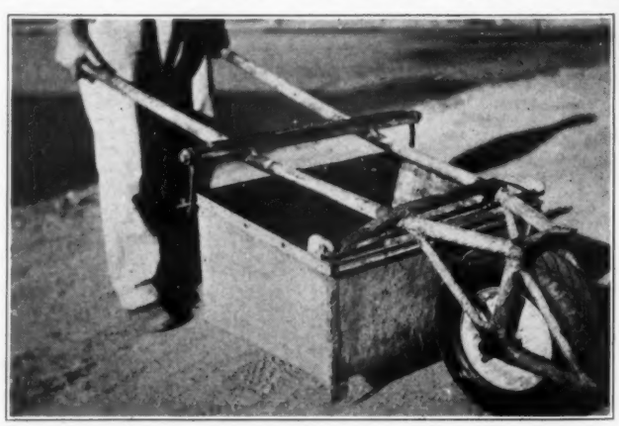
Containers Placed Next to Tank Ready for Skimmings.

three times a minute, has been in continuous service for more than six months.

It may be thought that condensation or spray might eventually fill the float cylinder with water, and the writer admits having shared such a belief at one time. Convinced, however, by the plant chief operator who designed and built the valve, that if the float did eventually fill it could be easily drained and put back into service, the installation was permitted. Now it has been proven that the principle is sound. No water escapes through the valve.

Grease Collection and Incineration

At the district's treatment plant, grease is skimmed manually from the tanks and burned. For a number of years skimmings



Wheel Barrow Used for Transporting Skimmings Containers to Incinerator.

WALLACE & TIERNAN CO., INC.

Manufacturers of Chlorine and Ammonia Control Apparatus
Dry Chemical Feed Devices, etc.
NEWARK, NEW JERSEY

"The Only Safe Sewage Is a Sterilized Sewage"

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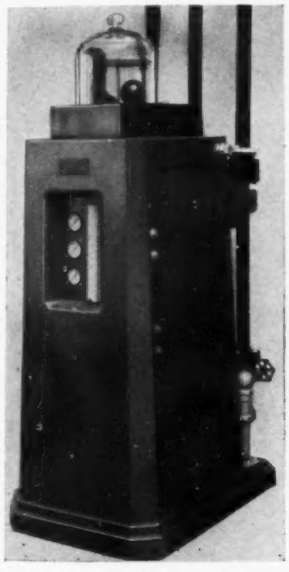
CHLORINATION OF SEWAGE

Of all chemicals used in sewage treatment, chlorine has by far the widest application. From simple disinfection to use as an adjunct to the most involved treatment process, chlorination has for many years been the versatile and valued aid of the man concerned with sewage disposal.

Chlorination is employed to stabilize raw sewage, control odors along trunk sewers or at treatment plants, protect masonry structures from disintegration, increase efficiency of filter beds and prevent filter ponding, improve sedimentation and removal of settleable solids, improve sludge digestion, prevent bulking in activated sludge plants, reduce biochemical oxygen demand and retard putrefaction in the receiving water course, disinfect effluents before discharge and as a necessary adjunct to nearly any process of chemical precipitation.

DISINFECTION

Regardless of what the preliminary process of sewage treatment may be, disinfection of the effluent before discharge has come to be regarded as a necessity. Protection of water supplies, of bathing places and of shellfish propagation beds all require efficient disinfection. That chlorination offers the one practical and effective means of sewage disinfection today is universally acknowledged by sanitarians and public health authorities.



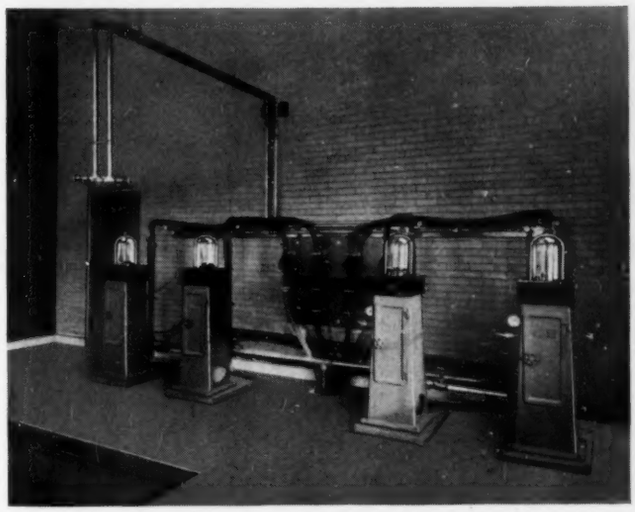
Master Visible Vacuum Chlorinator — W&T Visible Vacuum Control is now available in equipments ranging in capacity from .03 to 2000 pounds of chlorine per 24 hours.

ODOR CONTROL

Control of obnoxious odors from sewage treatment works, long outfall sewers and other disposal plant appurtenances is distinctly a field for chlorination. Neutralization of hydrogen sulphide (the gas responsible for these obnoxious odors) or prevention of its formation by controlled application of chlorine, is not only practical but also satisfactory in results and economy of operation.

B. O. D. REDUCTION

In order to prevent production of odor nuisance, foul appearance and death to fish life in streams receiving the effluents from sewage disposal plants, chlorination for B. O. D. reduction has become increasingly popular. Offering, as it does, a simple, easily controlled and relatively inexpensive means of supplementing other purification processes during periods of low stream flow or for permanent use at a plant where the dilution factor is low, chlorination has, in many cases, eliminated the necessity for extensive additions to the regular treatment works.



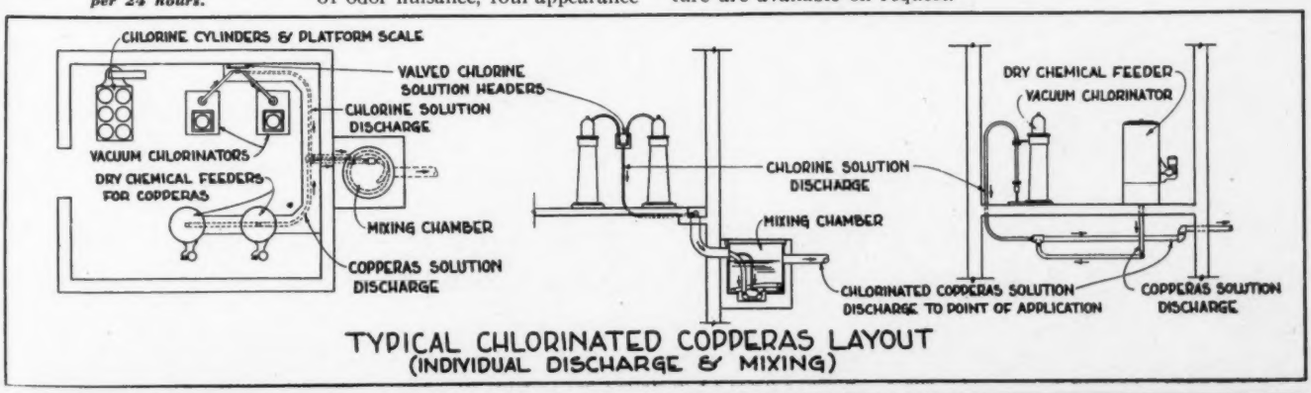
Installation of four Visible Vacuum Chlorinators at the New Haven, Conn., Sewage Disposal Plant.

IRON SALTS IN SEWAGE TREATMENT

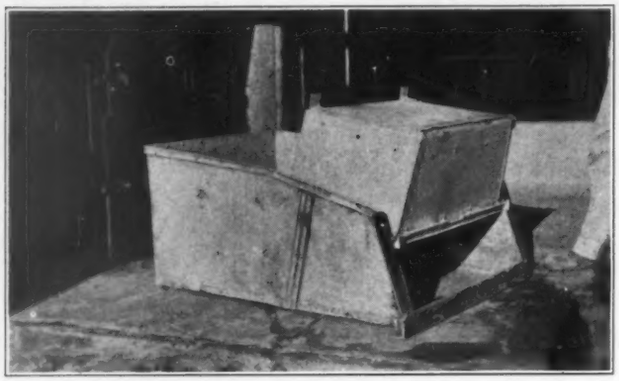
Lowered cost of chemicals and other contributing factors have greatly increased the popularity of iron salts for various uses in sewage treatment, odor control, sludge conditioning, chemical precipitation, etc.

In whatever form this treatment may be adopted, such as the manufacture of ferric chloride at plant site, the addition of ferric chloride or of ferric sulphate directly, or the use of chlorinated copperas, W&T are prepared to furnished the necessary equipment. Complete details on request.

W&T field representatives will gladly confer with you about any specific problem relating to the application of chlorine or iron salts in sewage treatment. Technical publications and literature are available on request.



TYPICAL CHLORINATED COPPERAS LAYOUT
(INDIVIDUAL DISCHARGE & MIXING)



Storage Pan at Incinerator.

were accumulated in galvanized iron cans and transported to drainage beds. When drained they were picked up in wheelbarrows and conveyed to the incinerator.

Handling the galvanized iron cans was a dirty and expensive item of labor as was the spreading on drainage beds and the reaccumulation and transportation to the incinerator. The grease draining beds were odorous in spite of all precautions and the incinerator ash was about 90 per cent sand—the latter being picked up with the grease from the beds.

The chief operator requested and received permission to construct the containers and transporting barrow.

The container or pan may be made any convenient size. That shown holds about 3 cubic feet. Placed in the bottom of the pan and standing on a rigid framework which elevates it an inch off the pan bottom, is a ¼-inch square mesh screen, the purpose of which is to provide drainage for the skimmings. The pan is so constructed that all drainage is toward the 1½-inch pipe shown in the right front of the pan at the base. Drainage from the skimmings goes directly back into the sewage tank.

The pan is filled with skimmings as they are taken from the sewage and permitted to drain for a couple of hours before being taken to the incinerator. Twelve such pans are in use at the plant.

For transporting the pans to the incinerator the pneumatic tire wheel-barrow (illustrated) was constructed and is used. The operator wheels up to the high side of the pan, steps across it and engages the forward cross brace in the two forward pan dogs, then upon lifting the wheel-barrow handles, the rod welded across the back of the pan catches in the two swinging hooks attached to the barrow handles, and the load is securely engaged. The penumatic tire prevents wear on concrete walls and cross walks; makes for easy rolling.

It may be seen that when the pan is lifted the slope of the pan bottom is reversed and any water shaken out of the screenings during transportation stays in the pan until it is set down.

At the incinerator a movable sheet metal storage pan is located in front of the charging door. The operator swings the loaded wheel-barrow handles over the storage pan, engages the pan's back rod in the two forward dogs in the storage pan, releases his load and then tips the screenings into the storage pan with a hook.

The operator's hands do not come in contact with the skimmings or the containers at any time and the curse has been eliminated from an operation job that was once a filthy task. Moreover, the work is greatly expedited.

The pans are cleaned daily with hot water and once a week with grease solvent. The pans and the wheelbarrow were all built in the plant shop by the plant operators.

Maximum Flow Gage for Sewers*

The accompanying sketch pictures the type of maximum flow gage, which has been installed in five manholes in the village of Shorewood in Milwaukee County, Wisconsin.

Metcalf and Eddy, in "American Sewerage Practice" (Vol. 1), under Maximum Flow Gages, describe a device that is substantially a stick with small vials attached along its length and inserted into a perforated pipe. The level of the mouth of the highest vial found full indicates the height to which the sewage has risen in the manhole. This design, however, has its disadvantages. First, the vials are breakable and entail considerable trouble in replacing. Second, it can not be used where the velocity exceeds eight feet per second.

The improvements in the Shorewood installation are:

First: It is cheap—the entire gage, made by a tinner and ready to install, costs very little.

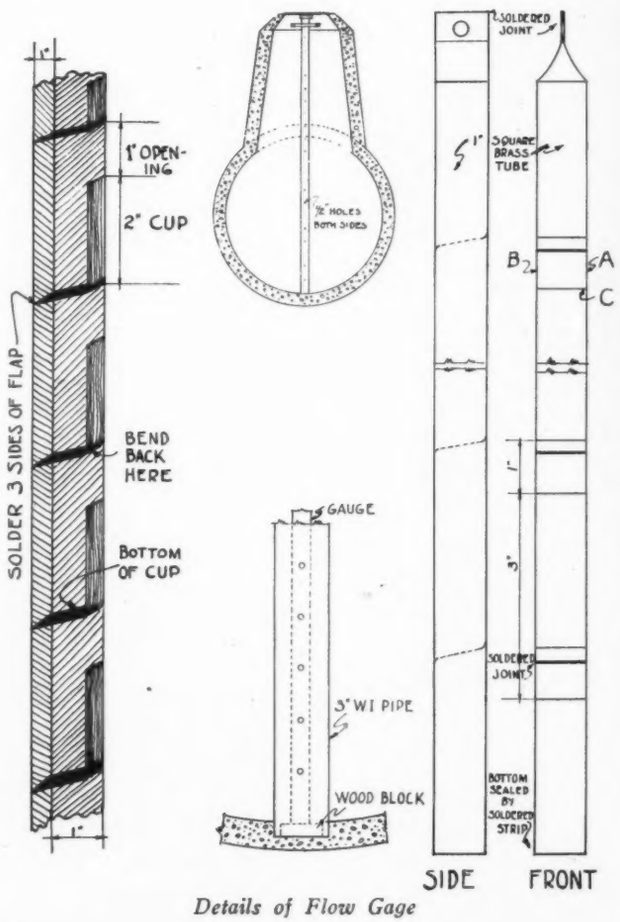
Second: It is not breakable and may be used in sewers regardless of velocity. Being made of brass or copper it is immune to corrosion.

A brief description may be helpful.—This gage is made of one inch (square) brass tubing, with one face (C on sketch) cut through at predetermined spacings. In the Shorewood design it is three inches. Then the corners are ground off on a power grinder to make edges A and B. The resulting flap is bent back and soldered in place to form the bottom of the pocket above. The block of wood is to raise the gage to the elevation of the invert of the sewer. The spacing of the pockets and the width of the mouths may be varied to suit circumstances. A perforated 2 in. W.I. pipe protects the gage.

In practice the gage has proven reliable and has served satisfactorily through several storms when the sewers were surcharged.

Credit for this design belongs to George Dewey Simms, Assistant Village Engineer, Shorewood, Wis.

*Contributed by Julius Lucoff, Milwaukee, Wis.



Details of Flow Gage

SEWER FLUSHING*

Good and Indifferent Practices

By JOHN D. WATSON

Consulting Engineer, Ruislip, England

This article reveals much pertinent to "Sewer Flushing" practices and presents what may be considered satisfactory flushing and what will prove a waste of effort and funds. The all important depth of flow in flushing, as compared to velocity flow without the needed depth, is pointedly emphasized. If we interpret correctly, many readers will find it necessary to consider some of our existing pseudo-flushing practices as little more than sewer "rinsing," after reading the depth—velocity discussion by Mr. Watson—an authority with a wealth of experience and years of observation to draw upon.

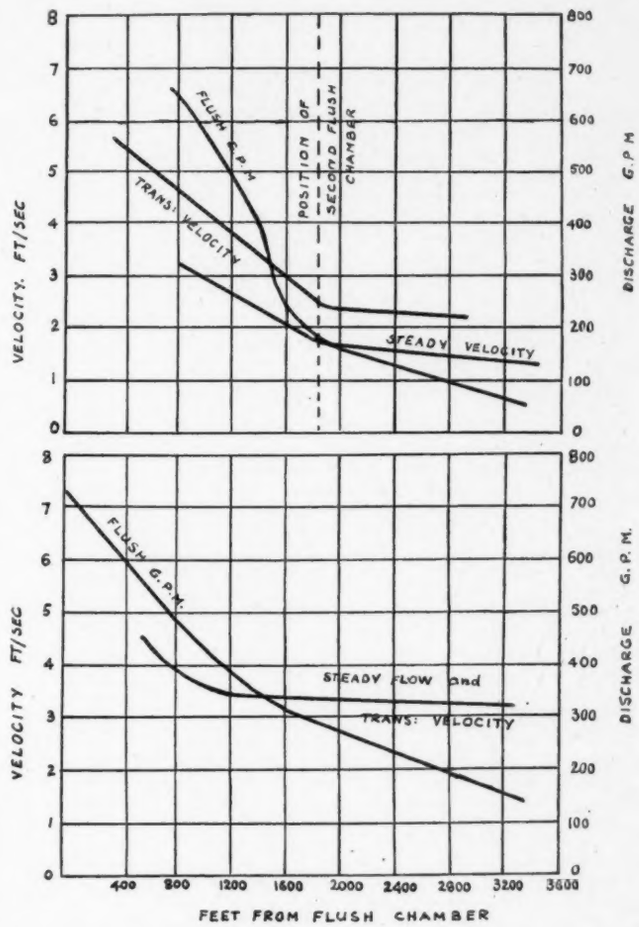
The basic condition upon which calculations for sewer flow should be made is that the sewer have a self-cleaning velocity. In other words, it should never tend to silt up even though the dry weather flow condition persists for long periods while at the same time it must be capable of taking storm water, unless it is wholly diverted from it. Provided they are properly constructed it is not usually difficult to give sewers a sufficient fall for this condition to be fulfilled. Main sewers will work with little or no trouble when laid on a grade of 1:1000 or less and, when the London Main Drainage was designed some 70 years ago, experiments showed that a velocity of 1½ miles per hour was sufficient, and very little cleaning is necessary in these sewers today. They vary from the familiar oval section of 4-ft. x 2-ft. and 8-in. to circular sewers of 12-ft. diameter. They are mainly built of brick.

Trouble is rather more likely to occur in the smaller branch sewers which have to be put in of a size to allow of increasing population so that for perhaps 10 or 20 years, normal flows are insufficient to maintain a self-cleansing velocity; and, while it is usually possible to divert surface water into them, it usually has to be kept out in order to save pumping and purification costs. The system adopted at one time at Hamburg, of constantly flushing the main sewers from a small river, enabled them to be laid at 1:3000, and to be run practically half full continuously, but that principle has rarely been adopted. The usual practice, when artificial flushing is resorted to, being either to provide gates to dam back the flow and then to release the pent up sewage for the purpose; or the use of tanks operated by an automatic syphon, the latter arrangement being as a rule the better one.

The Great Importance of Depth in Flushing

When arranging for it the important points to bear in mind are, that the flush is not going to be effective over any great distance, and that it is the depth of flow over the invert of a sewer which is the most effective in moving the material which is the main cause of obstruction. That of course, is the condition intended to be provided by the oval sewer, silt being usually the main cause of the trouble in the present connection. In the form of road detritus, though it may reach the sewers mainly in times of storm when there should be sufficient velocity to carry it to the outfall, road detritus in the average condition has been found by experiment to require a velocity of nearly 1-ft./sec. to keep it on the move and if small pieces of broken stone and similar material get into the sewer (which by some unaccountable means they do) such, according to size, will require a velocity of 2½ to 3½-ft./sec. to move them. Incidentally, it is such obstructions in the first instance, as a rule, which cause a general obstruction to build up.

Such material always moves along with a speed of travel less than that of the stream (usually not more than half) and though 2½-ft./sec. flow velocity may move a piece of stone it will only barely do so in 1-in. depth of water. But, if the depth be increased to 6-in. it will roll along quite easily at 2-ft./sec., confirming the contention already made that it is the depth of liquid in the sewer that is the really important factor in keeping it clean. Therefore, the conclusion to be reached, is that, in circular sewers at all events and more particularly in the average branch up to 30-in. dia., the basic cause of silting is *insufficient depth* of flow *rather than velocity;* and, especially is this evident in lateral sewers which only receive intermittent discharges from the dwellings connected to them. Thus, deposits commence which ought to be periodically flushed away because if they are not removed, although they might not immediately render the sewer inactive, they cause a filmy growth (slime) to appear on the pipe wall. This growth in turn further reduces the velocity, and so matters go from bad to worse with the additional evil of the sewage becoming septic and producing large volumes of sewer gas, with its well known attendant evils.



Curves Revealing Relationships Between Depth of Sewer Flush (Rate of Flush Discharge) and Effects Down-Sewer

This can be demonstrated in a simple manner by purposely putting some coarse sand or fine gravel in a sewer. Then it will be found that while motion is set up by dragging action, the particles are more or less lifted up into the stream and further motion is carried on by the added effect of suspension. The greater volume of material is naturally carried in the lower layers of the stream, the total quantity being proportional to the depth. Motion, too, will be seen to be from the sides of the sewer towards the centre, the major portion of the suspended matter being carried along the centre of the stream. The amount and the size of the material being carried in suspension

*From WATER WORKS AND SEWERAGE, August, 1937.

depends upon the velocity of the stream and its depth of flow. But, to a much greater extent depth is controlling, because in appreciable depth of liquid the particles are thrown to a greater height; and, as the velocity of descent of the particles is the same in both cases, the deep stream carries the particle further owing to the greater opportunity of remaining suspended.

Effects of Flushing

The conclusions to be reached, therefore, are that as a general rule it is advisable to provide means for flushing pipe sewers when they are laid at flatter gradients than those listed below:

12-in.....1:300	21-in.....1:600
15-in.....1:400	24-in.....1:700
18-in.....1:500	27-in.....1:800
30-in.....1:900	

Between 2,000 and 3,000 gallons at a flush, according to the size of the sewer and provided it is released once or twice every 24 hours, usually suffice. In any event it should be an amount that, when it does come into the sewer, practically fills it at that point. This, because the depth of the flushing wave near its point of origin decreases as it moves downstream to a point at which the depth and velocity are but little affected by the discharge. As an example, one can consider a 12-in. sewer flush by a 1,500-gallon tank through a 10-in. syphon in 1¼ minutes.

On the accompanying chart the upper set of curves relate to such a sewer laid at 1:630. One curve reveals transmission velocity, the other steady-flow velocity. As regards the former, the rate of transmission, at the commencement of the flush and at different distance from the flushing chamber, is that which would give the maximum scouring velocity, assuming the flush to be discharged into an empty sewer. This velocity lasts but a few seconds and its effect reaches but a short distance. In the matter of the steady-flow velocity, during the period when the maximum volume of flushing water is passing at different distances from the flushing chamber, it will be observed that this velocity lasted for a minimum period of 1 min., the period increasing with the distance from the flushing chamber. There is also a third curve which reveals the maximum volume of flushing water in gallons per minute at different distances from the flush chamber. From this curve, the effect of varying the amount of flush water discharged per minute can be determined. The lower set of two curves, in comparison, relates to a 9-in. sewer having a flush of 750 gallons for one minute.

Facts and Conclusions

The principal facts which become apparent from an examination of these curves are that:

(1)—The velocity dies off rapidly at first until it attains a certain value after which the diminution is small. As a result the flush is transmitted over an appreciable distance, probably about one mile.

(2)—With flat gradients, the velocity when the maximum volume of flush water is passing is less than the rate of transmission at the commencement of the flush, the difference gradually decreasing as the gradient decreases until the velocities are identical—such being indicated by the lower graph.

One can conclude, therefore, that the slope of the advancing flush will gradually flatten as the distance from the flushing chamber increases except where the gradient is sufficient to secure a high velocity. It is noticeable, also, how the steady flow velocity is over 3-ft./sec. at a distance of more than 3,400 ft. from the flush chamber. If, therefore, the sewer gradient is reasonably good, though appreciably less than that above set out, a good flush (rapidly discharged) will keep a sewer clean for at least half a mile even though its capacity be considerably in excess of normal dry weather flow requirements. And that, as already indicated, is the main purpose of artificial flushing.

CHART FOR CONVERTING GRAINS PER GALLON TO POUNDS PER MILLION AND THE REVERSE

Courtesy W. Donaldson and Fuller & McClintock, Engineers

POUNDS OF CHEMICAL REQUIRED PER HOUR FOR VARIOUS PUMPAGES & DOSES

PUMPAGE		DOSE - POUNDS PER MILLION GALLONS															
MILLION GALLONS 24 HRS.	THOUSAND GALLONS PER HOUR	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
		DOSE - GRAINS PER GALLON															
		.07	.14	.21	.28	.35	.42	.49	.56	.63	.70	.77	.84	.91	.98	1.05	1.12
1.0	41.7	.417	.833	1.25	1.67	2.08	2.50	2.92	3.33	3.75	4.17	4.58	5.00	5.42	5.83	6.25	6.67
1.5	62.5*	.625	1.25	1.88	2.50	3.13	3.75	4.38	5.00	5.63	6.25	6.88	7.50	8.13	8.75	9.38	10.0
2.0	83.3	.833	1.67	2.50	3.33	4.17	5.00	5.83	6.67	7.50	8.33	9.17	10.0	10.8	11.7	12.5	13.3
2.5	104	1.04	2.08	3.13	4.17	5.21	6.25	7.29	8.33	9.38	10.4	11.5	12.5	13.5	14.6	15.6	16.7
3.0	125*	1.25	2.50	3.75	5.00	6.25	7.50	8.75	10.0	11.3	12.5	13.8	15.0	16.3	17.5	18.8	20.0
3.5	146	1.46	2.92	4.38	5.83	7.29	8.75	10.2	11.7	13.1	14.6	16.0	17.5	19.0	20.4	21.9	23.3
4.0	167	1.67	3.33	5.00	6.67	8.33	10.0	11.7	13.3	15.0	16.7	18.3	20.0	21.7	23.3	25.0	26.7
4.5	187	1.88	3.75	5.63	7.50	9.38	11.3	13.1	15.0	16.9	18.8	20.6	22.5	24.4	26.3	28.1	30.0
5.0	208	2.08	4.17	6.25	8.33	10.4	12.5	14.6	16.7	18.8	20.8	22.9	25.0	27.1	29.2	31.3	33.3
5.5	229	2.29	4.58	6.88	9.17	11.5	13.8	16.0	18.3	20.6	22.9	25.2	27.5	29.8	32.1	34.4	36.7
6.0	250*	2.50	5.00	7.50	10.0	12.5	15.0	17.5	20.0	22.5	25.0	27.5	30.0	32.5	35.0	37.5	40.0
6.5	271	2.71	5.42	8.13	10.8	13.5	16.3	19.0	21.7	24.4	27.1	29.8	32.5	35.2	37.9	40.6	43.3
7.0	292	2.92	5.83	8.75	11.7	14.6	17.5	20.4	23.3	26.3	29.2	32.1	35.0	37.9	40.8	43.8	46.7
7.5	312	3.13	6.25	9.38	12.5	15.6	18.8	21.9	25.0	28.1	31.3	34.4	37.5	40.6	43.8	46.9	50.0
8.0	333	3.33	6.66	10.0	13.3	16.7	20.0	23.3	26.7	30.0	33.3	36.7	40.0	43.3	46.7	50.0	53.3
8.5	354	3.54	7.08	10.6	14.2	17.7	21.3	24.8	28.3	31.9	35.4	39.0	42.5	46.0	49.6	53.1	56.7
9.0	375*	3.75	7.50	11.3	15.0	18.8	22.5	26.3	30.0	33.8	37.5	41.3	45.0	48.8	52.5	56.3	60.0
9.5	396	3.96	7.92	11.9	15.8	19.8	23.8	27.7	31.7	35.6	39.6	43.5	47.5	51.5	55.4	59.4	63.3
10.0	417	4.17	8.33	12.5	16.7	20.8	25.0	29.2	33.3	37.5	41.7	45.8	50.0	54.2	58.3	62.5	66.7
10.5	437	4.38	8.75	13.1	17.5	21.9	26.3	30.6	35.0	39.4	43.8	48.1	52.5	56.9	61.3	65.6	70.0
11.0	458	4.58	9.17	13.8	18.3	22.9	27.5	32.1	36.7	41.3	45.8	50.4	55.0	59.6	64.2	68.8	73.3
11.5	479	4.79	9.58	14.4	19.2	24.0	28.8	33.5	38.3	43.1	47.9	52.7	57.5	62.3	67.1	71.9	76.7
12.0	500*	5.00	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
12.5	521	5.21	10.4	15.6	20.8	26.0	31.3	36.5	41.7	46.9	52.1	57.3	62.5	67.7	72.9	78.1	83.3
13.0	542	5.42	10.8	16.3	21.7	27.1	32.5	37.9	43.3	48.8	54.2	59.6	65.0	70.4	75.8	81.3	86.7
13.5	562	5.63	11.3	16.9	22.5	28.1	33.8	39.4	45.0	50.6	56.3	61.9	67.5	73.1	78.8	84.4	90.0
14.0	583	5.83	11.7	17.5	23.3	29.2	35.0	40.8	46.7	52.5	58.3	64.2	70.0	75.8	81.7	87.5	93.3
14.5	604	6.04	12.1	18.1	24.2	30.2	36.3	42.3	48.3	54.4	60.4	66.5	72.5	78.5	84.6	90.6	96.7
15.0	625*	6.25	12.5	18.8	25.0	31.3	37.5	43.8	50.0	56.3	62.5	68.8	75.0	81.3	87.5	93.8	100.0

* Exact Values

1 grain per gallon = 143 pounds per million gallons = 5.95 lbs. per hour for each million gallons
0.70 " " " = 100 " " " " = 4.17 " " " " " " "

Courtesy Fuller and McClintock, Engineers

Example: What weight of Chemical must be fed each hour to give a 70 lb dose for a pumpage of 8.0 M.G.D. Opposite 8.0 M.G.D and under 70 find 23.3, which is the correct weight.

Note: It is now becoming modern practice to record and report all chemical dosages in pounds per million (P.M.G.) and thereby have simplification in reporting and recording, rather than using the older scheme involving grains per gallon, parts per million, etc.

GREASE REMOVAL

Grease Separation Enhanced by "Aero-Chlorination"

*Part I—Experiences at Woonsocket, R. I.**

By HARRY A. FABER

Research Chemist, The Chlorine Institute, Inc., New York, N. Y.

Only limited study has so far been given to the problem of removing grease from sewage.

In several activated sludge plants provision has been made to partially remove oil, grease and soaps by means of a short period of diffused air aeration and removal thereafter as scum. Not all grease rises to the surface by such treatment but, because it remains in an emulsified form or exists as a coating on heavier particles, is carried with the sewage flow. This aeration and swimming process is only partially effective in grease removal and little data is available as to the most efficient tank design or air application.

In consequence of indications noted at several plants employing pre-chlorination of sewage and, in particular some observations during chlorination experimentation at the Baltimore Treatment Works, it was decided to undertake an experiment wholly confined to grease removal.

Plant Scale Experiment

For two reasons, the activated sludge plant at Woonsocket, R. I., appeared, a desirable site for the experiment. First, the physical equipment of this plant is suitable. A grease skimming tank using aeration is in regular operation ahead of the primary settling tanks. Second, the Woonsocket sewage has a high and variable grease content because it receives wastes from such industries as wool scouring, rayon manufacture, and weaving processes.

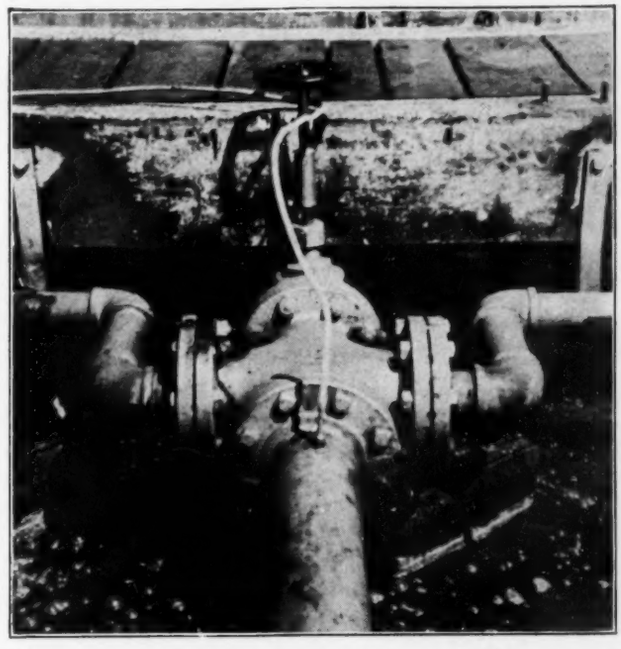
Aeration during a six minute detention period (at normal flows) is provided. The study was confined to a comparison of aeration at the usual rate, with and without the addition of chlorine to the air input.

To secure the maximum effect of chlorination it seemed desirable to add chlorine as near the point of air-diffusion as possible. For this reason it was decided to confine the study to the introduction of gaseous chlorine directly into the compressed air line. Previous experience had indicated the value of efficient flash type distribution of the chlorine which would be accomplished in this scheme. Other experiences had indicated that the only point on the air-diffusion system at which minor chlorine injections might prove damaging was to the drop pipes immediately above the submerged air-diffusers.

Chlorine Dosages

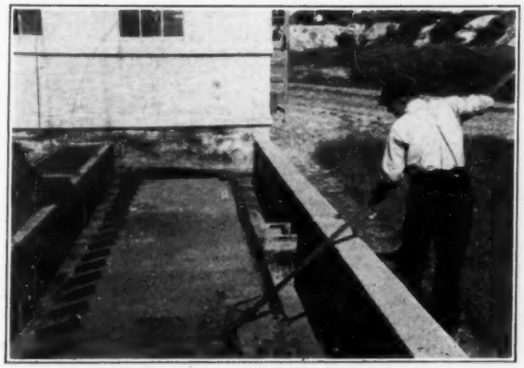
The original plan was to study the relation between chlorine dosage and grease removal results. A limiting factor at Woonsocket soon became apparent, however, in that the porous tube air diffusers are located at a depth of only three feet below the surface of the skimming tank. Because of the shallow depth, air bubbles rise to the surface with only a relatively short travel and consequently brief air-sewage contact period. Thus the chlorine content of the air could not be large or, else, unabsorbed gas would be released at the surface and chlorine would be wasted to the atmosphere. Chlorination was, therefore, adjusted to feed at slightly below the point at which a chlorine odor became perceptible at the surface of the sewage.

From Table 1 it will be noted that the average chlorine dose



Chlorine Gas Feed-Tube Connected Into Air Header of Grease Separation Tanks.

Close-Up of the Grease Froth Accumulating Within the Baffled "Trap." Lifted by Blowing With Chlorinated Air in the Center Compartment, Wave Action Pockets It in the Traps on Either Side.



Skimming the Traps During Chlorination. More Work for the Operators; But Less Grief in the Plant Beyond.

*From WATER WORKS AND SEWERAGE—May, 1937.

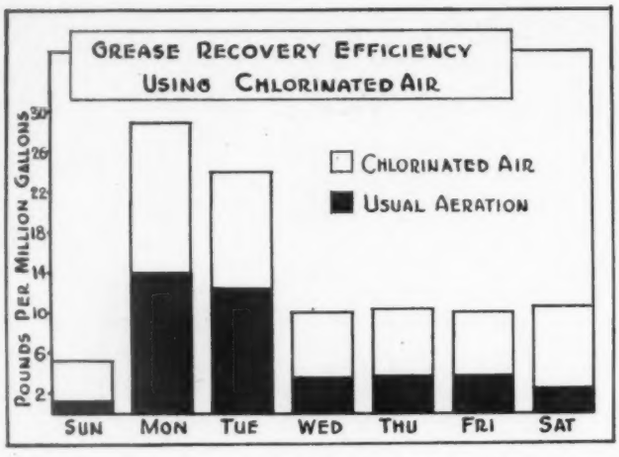


Fig. 1—Graphical Comparison of Grease Yields—With and Without Chlorinated Air.

was under 1.5 p.p.m., when calculated on sewage flow. Tests for chlorine in the treated sewage at no time showed the presence of any residual. There is some evidence that a somewhat increased dose would have resulted in greater effectiveness in freeing grease, had the physical conditions of depth and adsorption permitted.

TABLE 1—GREASE RECOVERY EFFICIENCY USING CHLORINATED AIR

	Pounds Wet Grease per m.g. Sewage		—Additional Yield—		P. P. M.*
	Usual Aeration	Chlorinated Aeration	Yield Pounds per m. g.	Per Cent Increase	Chloride Applied
Sunday	1.3	5.3	4.0	408	1.51
Monday	14.0	29.0	15.0	207	1.47
Tuesday	12.2	23.0	10.8	189	1.47
Wednesday	3.6	10.0	6.4	278	1.41
Thursday	3.9	10.3	6.4	264	1.68
Friday	3.9	10.0	6.1	256	1.40
Saturday	2.4	10.6	8.2	442	1.38

*Calculated from total chlorine applied and total sewage flow each day—therefore the average dosage.

Measurement of Released Grease

It appeared that the most dependable measure of efficiency (certainly the most practical) would be to remove and weigh the total grease collected in the form of scum on the tank. Because of the baffle arrangement of the tank, grease could be collected over an entire 24 hour period—see picture. By using a screen skimming device for coarse scum and a cheesecloth skimmer for fine scum the daily accumulation could be determined. The skimmings are drained to allow easily separable water to run off and were weighed in light metal (tarred) cans.

By weighing the relatively large 24 hour accumulation of grease, it is believed that reasonable accuracy of grease yield comparison was obtained. In this way, actual plant operating conditions were measured in a practical manner.

Results of Operation

It was noted that, as would be expected, the grease yield on different days of the week showed wide variation. While it is recognized that a study confined to two weeks of operation may not be typical of yearly operation, at least the daily variation and an indication of chlorination effectiveness should be proven.

Daily sewage flow was recorded and varied between 3.0 m.g.d. and 3.8 m.g.d. During the two week period the flow for corresponding days showed no more than 0.2 m.g.d. variation. In order to facilitate a comparison of removal results, the grease recovered has been computed on a million gallon basis.

These results are given in Table 1. They indicate that a gaseous chlorine dose, averaging less than 1.5 p.p.m. (based on sewage treated), effected increases in grease removal ranging from 189 to 442 per cent. While there is wide variation in the daily amount collected, it appears that from Monday through Friday the per cent of increase in yield is surprisingly constant. Saturday and Sunday grease collections, while less in amount, show higher percentage yields, which vary from 408 to 442 per cent increase during chlorination. These results are compared in Table 2. On these days practically no industrial waste is received at the plant and the sewage is almost entirely domestic in nature, yet the percentage yield of grease was practically doubled. Figure 1 shows graphically the pounds of grease per million gallons of sewage as collected by the two methods.

TABLE 2—GREASE RECOVERY VARIATION WITH TRADE WASTE IN SEWAGE

Wet grease, lb./m.g.	Saturday and Sunday	Monday to Friday, Incl.
(a) By usual aeration	1.85	7.5
(b) Chlorinated aeration	7.95	16.5
Increase in yield	430%	220%
Chlorine dose applied (P.P.M.)	1.45	1.48

Discussion of Results

While it was possible, in the Woonsocket experiment, to apply only a small dose of chlorine to the diffuser system, the result indicates that a definite increase in grease separation can be accomplished by this method with modest chlorine dosages. It was expected that the recovery of grease from this sewage, which contains a high grade content because of the industrial wastes present, would be more marked than from purely domestic sewage. The limited runs indicate, however, that the yield of grease from domestic sewage, when blown with chlorinated diffused air, may prove to be proportionally higher.

The effectiveness of this method of grease removal, as applied to a strictly domestic sewage, is to be studied by C. E. Keefer and staff in more detail during 1937, at the main treatment works of Baltimore, Md. The results of varying aeration time, chlorine dose, and other factors to be studied should indicate significant points in the process.

GREASE REMOVAL

Part II—Results at Baltimore, Md.*

By C. E. KEEFER[1] and E. C. CROMWELL[2]

Bureau of Sewers, Baltimore, Maryland

During the past ten years sanitary engineers have been devoting considerable attention to the removal of grease from raw sewage. The method which was developed in the Ruhr District[1] in Germany and which has become more or less standardized, has been to aerate sewage as it flows through a tank providing a detention period of about three minutes. Such short aeration periods have been shown to generally lack adequacy without subsequent detention of the sewage.

An improvement to this method of grease removal was investigated by Faber,[2] of the Chlorine Institute, at the Woonsocket, R. I., treatment plant. In the new method gaseous clorine was injected into the air pipe serving the grease removal tank. The results of this full scale work indicated that when 1.5 p.p.m. of chlorine were used an increase in grease removal from 189 to 442 per cent, on various days of the week, was obtained as compared with the use of air alone. A similar group of experiments since conducted at Baltimore have given increases ranging from 149 to 847 per cent.

Method of Conducting Experiments

Raw sewage, which had passed through mechanically-cleaned coarse screens with ¾-in. clear openings, was pumped into two wood-stave tanks here pictured. Each tank is 8 ft. in diameter and 5 ft. deep. The sewage entered the tanks at the top through a wooden distribution box, which was adjusted in order to divide the flow equally to the two tanks. At the bottom of each tank there were three "Aloxite" tubes (30 in. long and 1¾ in. diameter) for the distribution of air. The air was measured with two rotary-type gas meters. Chlorine was applied to the air pipe serving one of the tanks; the same ratio, as nearly as practicable, of air without chlorine was applied to the other tank. The diffuser tubes were as nearly alike as manufacture permits and were located similarly in each tank.

Results

Twenty-two preliminary runs, which fall into three groups, were made. (See Table I.) The detention periods of the sewage in the tanks for the three groups of runs were 5, 10 and 15 minutes. Each run, which was started at about 10 a. m. and concluded at 3 p. m., lasted for 5 hours, and was purposely arranged during the time when the sewage was strongest.

Five-minute Aeration Period: When the detention period was 5 minutes, an average of 0.064 cu. ft. of air per gallon of sewage was used. The quantity of chlorine applied was varied from 1 to 10.0 p.p.m.* When the sewage was treated with 1.0 p.p.m. of chlorine, the increase in the quantity of scum was a minimum but amounted to more than twice the yield when air alone was used. Applying 5.0 p.p.m. of chlorine resulted in 7.5 times as much scum being collected. With larger quantities of chlorine, however, the increase became less. It should be pointed out that when more than 3.0 p.p.m. of chlorine were used some of it was not absorbed but escaped into the atmosphere.

Ten-minute Aeration Period: With a 10-minute aeration period, an average of 0.146 cu. ft. of air per gallon of sewage was used. The increase in the yield of scum varied from 1.62 to 5.30 fold, the latter increase occurring with the application of 8.0 p.p.m. of chlorine.

Fifteen-minute Aeration Period: An average of 0.216 cu. ft. of air per gallon of sewage was used when the detention period was 15 minutes. A *minimum* increase of 238 per cent in the volume of scum resulted when using 1.0 p.p.m. of chlorine, and a maximum of 847 per cent when applying 5.0 p.p.m. of chlorine.

*Note—In this work all chlorine dosages in p.p.m., for simplicity sake, refer to the dosage in terms of the volume of sewage, without consideration of the air volume involved.

TABLE I.

EFFECT OF CHLORINE AND AIR ON THE SEPARATION OF SCUM AND GREASE FROM RAW SEWAGE.

(Duration of each run: 5 hours.)

Run No.	Day of Test	Air Treatment: Air, Cu. Ft. Per Gal.	Air Treatment: Scum (Dry), Lbs. Per Mil. Gal.	Air Treatment: Grease (Dry Solids, Basis), Pct.	Air and Chlorine Treatment: Chlorine Used p.p.m.*	Air and Chlorine Treatment: Scum (Dry), Lbs. Per Mil. Gal.	Air and Chlorine Treatment: Grease (Dry Solids basis) Pct.	Increase in Scum with Cl_2 Treatment
		Detention Period—5 Minutes						
1.	Monday	.061	1.809	59.2	1.0	3.776	61.5	2.09
2.	Thursday	.070	.844	65.0	2.0	2.278	59.0	2.70
3.	Friday	.063	.788	60.0	3.0	1.792	57.9	2.27
4.	Monday	.066	1.492	52.7	4.0	9.789	51.5	6.56
5.	Tuesday	.063	1.169	52.7	5.0	8.766	53.8	7.50
6.	Tuesday	.057	1.667	65.2	8.0	8.375	59.3	5.02
7.	Friday	.069	1.060	64.4	10.0	4.400	57.9	4.15
	Average	.064						
		Detention Period—10 Minutes						
8.	Tuesday	.114	1.424	61.1	1.0	2.900	62.1	2.04
9.	Friday	.157	.752	49.3	2.0	2.649	62.4	3.52
10.	Monday	.146	2.986	51.4	3.0	4.851	54.5	1.62
11.	Thursday	.139	1.739	59.9	4.0	4.974	54.7	2.86
12.	Friday	.169	1.869	56.3	5.0	6.339	54.2	3.39
13.	Tuesday	.144	.591	67.7	8.0	3.130	67.8	5.30
14.	Thursday	.151	1.952	64.2	10.0	4.435	57.1	2.27
	Average	.146						
		Detention Period—15 Minutes						
15.	Thursday	.213	1.573	53.7	1.0	3.750	63.1	2.38
16.	Wednesday	.192	1.277	51.1	2.0	4.442	67.7	3.48
17.	Tuesday	.201	1.392	52.4	3.0	4.810	55.8	3.46
18.	Thursday	.217	1.795	63.7	4.0	6.375	61.1	3.55
19.	Wednesday	.232	2.509	59.5	5.0	21.248	51.0	8.47
20.	Tuesday	.243	2.143	64.4	8.0	5.143	55.5	2.40
21.	Thursday	.211	1.867	64.8	10.0	6.286	57.8	3.37
	Average	.216						

*The chlorine dosages, for simplicity, were based on sewage flow treated, and have no relationship to the air-chlorine ratios.

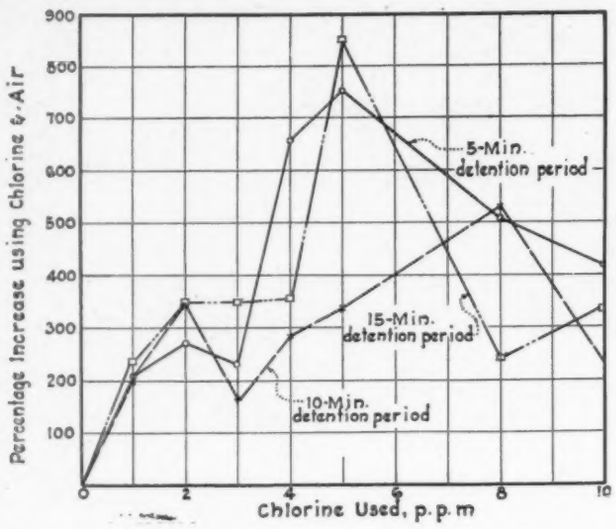
Note.—With a diffuser submergence of roughly 4 ft., a slight chlorine odor was noted when adding 3 p.p.m. of chlorine mixed with the air, and increased with higher dosages.

Twenty-four-hour Aeration Period: In addition to making the 5-hr. tests four runs were made, each for 24 hr., in order to study the effect of the chlorine and the air throughout the entire day. The amount of chlorine used was 2 p.p.m. during two of the tests and 4 p.p.m. during the other two, with detention periods of 5 and 10 minutes. As indicated in Table II, the use of 2 p.p.m. of chlorine increased the yield of scum 149 per cent with a 5-minute detention period and 213 per cent with a 10-minute detention period or an average of 181 per cent. When 3 p.p.m. of chlorine were used, the increase in the yield was 327 per cent for a 5-minute detention period and 231 per cent for a 10-minute detention with an average of 279 per cent.

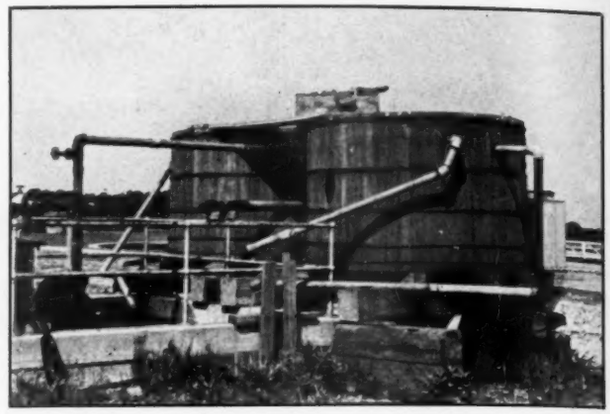
*From WATER WORKS AND SEWERAGE—Feby., 1938.

[1]Engineer in charge of Treatment Works.

[2]Chief chemist, Back River Treatment Works.



Increase in Scum Production by Applying Chlorine and Air to Sewage as Compared with Air Alone. Curves From Air Alone All Lie in the Zero Line, as the Amounts of Scum From Air Alone Were Taken as the Base in Each Test Plotted.



Twin Experimental Tanks Used in Many Tests at the Back River Plant—This Time on the "Aero-Chlorination" Work. Sewage Pump on Left; Overflow and Regulatory Flow-Splitting Box on Top of Tanks; Portable Chlorinator Housing Is Visible Behind the Right Tank; the Air Meters Are Also Behind Tanks.

TABLE II.

SEPARATION OF SCUM FROM RAW SEWAGE WHEN USING CHLORINE AND AIR FOR 24-HOUR PERIODS.

SCUM—(dry basis)

Period of Treatment	Air Alone lbs./mg.	Air and Chlorine lbs./mg.	Increase in Scum due to Chlorine
Chlorine (2 p.p.m.) Air (0.082 cu.ft. per gal.) Detent'n (5 min.)			
11 A.M.— 2 P.M.	2.576	3.253	1.26
2 P.M.— 5 P.M.	2.613	3.886	1.49
5 P.M.— 8 P.M.	6.798	7.718	1.14
8 P.M.—11 P.M.	4.397	7.569	1.72
11 P.M.— 2 A.M.	3.649	8.189	2.24
2 A.M.— 5 A.M.	2.505	2.170	0.87
5 A.M.— 8 A.M.	1.297	1.212	0.93
8 A.M.—11 A.M.	5.789	13.152	2.27
Average	3.703	5.894	1.49
Chlorine (2 p.p.m.) Air (0.165 cu. ft. per gal.) Detent'n (10 min.)			
12 N.— 3 P.M.	2.401	9.140	3.81
3 P.M.— 6 P.M.	2.318	3.859	1.66
6 P.M.— 9 P.M.	2.874	6.520	2.27
9 P.M.—12 M.	2.764	4.570	1.65
12 M.— 3 A.M.	2.401	3.859	1.61
3 A.M.— 6 A.M.	1.029	2.288	2.22
6 A.M.— 9 A.M.	1.605	1.801	1.12
9 A.M.—12 N.	0.755	2.018	2.67
Average	2.019	4.257	2.13
Chlorine (3 p.p.m.) Air (0.080 cu. ft. per gal.) Detent'n (5 min.)			
11 A.M.— 2 P.M.	1.815	9.331	5.14
2 P.M.— 5 P.M.	4.629	18.553	4.01
5 P.M.— 8 P.M.	11330	27.296	2.41
8 P.M.—11 P.M.	2.138	10.708	5.01
11 P.M.— 2 A.M.	3.360	10.473	3.21
2 A.M.— 5 A.M.	2.455	7.291	2.97
5 A.M.— 8 A.M.	1.531	2.220	1.45
8 A.M.—11 A.M.	4.827	9.382	1.94
Average	3.998	11.907	3.27
Chlorine (3 p.p.m.) Air 0.165 cu. ft. per gal.) Detent'n (10 min.)			
10 A.M.— 1 P.M.	2.606	3.067	1.18
1 P.M.— 4 P.M.	2.901	12.376	4.27
4 P.M.— 7 P.M.	6.715	18.707	2.79
7 P.M.—10 P.M.	6.351	14.232	2.24
10 P.M.— 1 A.M.	3.086	6.425	2.08
1 A.M.— 4 A.M.	4.081	4.746	1.16
4 A.M.— 7 A.M.*	1.262	3.081	2.44
Averages, 24 hr. Runs....	3.857	8.948	2.31

*Run stopped because of freezing weather.

ARMCO CULVERT MFRS. ASSOCIATION

MIDDLETOWN, OHIO

FABRICATING PLANTS THROUGHOUT THE UNITED STATES AND CANADA

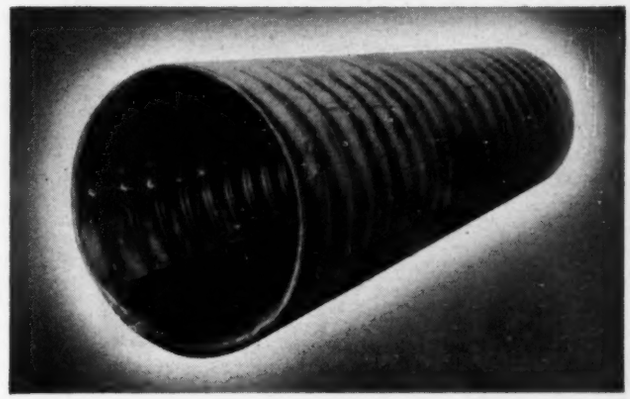
ASBESTOS BONDED ARMCO SEWER PIPE

MULTI PLATE PIPE AND ARCHES

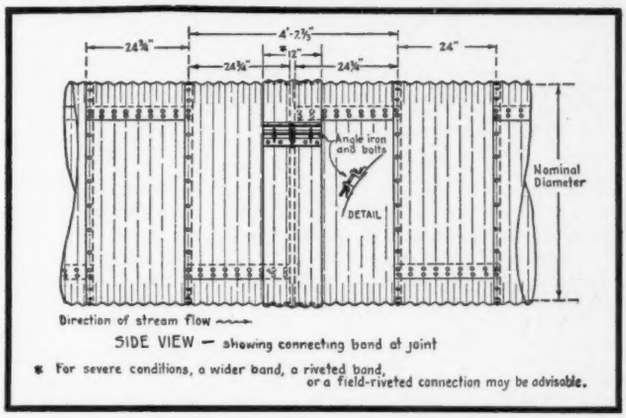
PERFORATED METAL PIPE • FLUMES

BIN-TYPE RETAINING WALLS

DRAINAGE GATES • STANDARD FULL-ROUND AND PART-CIRCLE CULVERTS



Asbestos Bonded Armco Sewer Pipe.



Fabrication details of Armco Sewer Pipe.

ARMCO SEWER PIPE

A full-round corrugated pipe made of galvanized ARMCO Ingot Iron. Paved in the bottom and fully coated with a special bituminous material which is mechanically bonded to the pipe by means of asbestos fibres embedded in the galvanized coating.

Armco Sewer Pipe is quickly available in diameters from 8 to 96 inches, including connecting bands and standard or special fittings. Individual lengths up to 20 feet. Write for 48-page illustrated book on sewers containing useful design information.

RECOMMENDED GAGES FOR ASBESTOS BONDED ARMCO SEWER PIPE

	DEPTH OF COVER (H), FEET								
Diam. D Inches	1 — 2	2¼ — 7	7½ — 10	11 — 15	16 — 20	21 — 25	26 — 30	31 — 35	36 — 40
12	16	16	16	16	16	16	16	16	16
15	16	16	16	16	16	16	16	16	16
18	16	16	16	16	16	16	16	16	14
21	16	16	16	16	16	16	16	14	14
24	16	16	16	16	14	14	14	14	14
30	14	14	14	14	14	14	12	12	12
36	14	14	14	14	14	12	12	10	10
42	14	14	14	12	12	10	10	8	8 *
48	14	14	14	12	12	10	8	8	8
54	12	14	12	10	10	8	8	8	8
60	12	12	* 12	10	8	8	8	8	8
66	12	12	12	8	8	8	8	8	8
72	10	12	10	8	8	8	8	8	8
84	8	10	8	8	8	8	8	8	8

Note: The gages shown are based on a maximum deflection of 5% for the following loadings:
1—Live Load = H 20 + 50% impact = 24,000 lbs. concentrated surface load.
2—Dead Load = Embankment (ordinarily heavier than ditch loading.)

*** For pipe below heavy black lines consult an Armco engineer for installation instructions.**

SEWAGE AND SLUDGE PUMPING[1]

By HENRY RYON[2]

Albany, N. Y.

General

During the past several years a very marked improvement has been made in the methods of pumping sewage and sewage sludge, and special pumps have been developed for this service. Only a few years ago, however, practically all sewage was lifted with pumps designed primarily for handling water.

The centrifugal dredging pump driven either by a steam engine or an electric motor was used with a fair degree of success at many stations. While this pump would handle sand and gravel satisfactorily, rags would wrap themselves around the impeller and necessitate frequent cleaning of the pump either through hand holes in the volute or by the removal of the side of the case. It was not very efficient and the head was limited. The smaller and higher speed centrifugal pump, used successfully for pumping water, gave more trouble, due to clogging, when used for pumping sewage, than the dredging pump.

Reciprocating pumps were used in many cases. These pumps clogged about as easily as the centrifugal pumps; and, if there were any sand or grit in the sewage, gave trouble due to the scoring of cylinders. At one or two large stations the crank and fly wheel pump was used and operated satisfactorily principally because of its large size. The ordinary duplex steam pump served in a few cases. The single acting triplex pump, equipped with ball valves, although not entirely free from clogging, proved to be the most satisfactory of the reciprocating pumps and was used, and is still being used, successfully for pumping both sewage and sludge. Its cost is, however, greater than that of a centrifugal pump and it is rather noisy. It is worth noting that the design of the most modern reciprocating sludge pumps have apparently been copied from the old single acting triplex pump.

At almost all of the old pumping stations the sewage was passed through bar or mesh screens to remove the rags and other solids from it before it reached the pumps. The cleaning of the screens always proved a laborious and unpleasant task, and did not entirely do away with the necessity of cleaning the pumps.

The Pneumatic Ejector

In order to eliminate the trouble of cleaning screens and pumps, the pneumatic or compressed air ejector was developed. This device, which was first used about fifty years ago, operates by allowing the sewage to flow into an iron or steel chamber and, when the chamber is full, automatically admits compressed air above the sewage thus forcing it out through the discharge line. The mechanism operates very successfully, and stories are told of ejectors having been lost for several years and when rediscovered were found to be operating satisfactorily. It requires, however, air compressors, air tanks, and other appurtenances which make the first cost and also the maintenance expensive. In addition to this, the efficiency is very low. The overall or wire to water efficiency when the compressors are operated by electricity vary generally from 10 to 20 per cent. At present, due to the improvements in the design of centrifugal pumps, ejectors are being used less and less except in the very small stations or for sludge and screenings handling.

Pump Impellers

The improvement in the centrifugal sewage pumps has been largely in the design of the impellers or runners. There are, in general, two types of pump impellers, the open and the closed. The open impeller gives larger water ways with the same size casing, but solids clog between the impeller and the casing and rags wrap around the impeller blades. Increasing the clearances to reduce clogging, of course, reduces the efficiency and does not prevent rags from stopping the flow. Open impellers, generally with only two blades, serve well in small sump pumps and also in sewage pumps of small capacities where a closed impeller small enough to give the desired capacity would not pass solids of any size. In most cases, however, the closed or semi-enclosed impeller is to be preferred.

In the design of closed impellers for handling sewage, the water passages have been made wider than in water pumps, all sharp edges and turns have been carefully avoided, thus reducing the chance of clogging to a minimum. As a general rule pumps with impellers of this type will pass solids having diameters about one pipe size smaller than the size of the pump. One manufacturer is producing a pump with a worm feed to force the solids to the impeller of the pump and also cut and crush them against hard steel bars running longitudinally of the screw case. Pumps of this type are giving satisfactory service in several western stations. A rather unique impeller is used in some English pumps. The impeller is open on the suction side and the blades are considerably wider at the shaft than at their ends. The edges of the blades pass very close to bars set on the inside of the case and macerate the solids entering the pump.

It is customary to require the impellers of the pumps to be made of bronze but with ordinary sewage there seems to be no advantage in the use of bronze as compared with that of cast iron. A few pumps have been installed having cast iron impellers coated with enamel and they are said to be giving satisfactory results. The manufacturers claim a slightly higher efficiency for this impeller than can be obtained with the bare metal impeller.

Submerged Vertical Pumps

For the smaller installations probably the submerged vertical centrifugal pump is the most commonly used. The sump may be made of cast iron or steel or may be of concrete. The motor and pump are both supported on a removable iron cover so that the pump can be lifted out of the sump for cleaning and repairs. Enough head room must, of course, be provided to allow the suction to clear the top of the sump when the pump is lifted out. It is also desirable that the discharge be brought up through the same plate so that it may be easily disconnected. In unheated pump houses, however, it is sometimes impossible to do this without danger of the sewage in the discharge line freezing. Where short separate discharges can be used, freezing can be avoided by omitting the check valves and allowing the sewage in the discharge pipe to flow back into the sump after each discharge. If screens are to be omitted it is usually advisable to provide a pump not smaller than 3 inches in size. Such a pump will have a capacity of from 50 to 300 gallons per minute, depending upon design of the impeller and the speed of the motor.

Float Controls

Sewage pumps are usually automatic in operation and the arrangement of the float control deserves more attention than it generally receives. The float may be connected to the electric switch either by a push rod or by a chain running over pulleys with a counterweight to balance the float. Either method operates satisfactorily if properly arranged. Floats that hang unprotected in the sump are apt to be moved sideways by the motion of the sewage causing the chain or rod to bind, or the rod to bend, making the float inoperative. In some designs the rod has a guide at the bottom to prevent such motion, but if the rod sticks in the guide or leaves the guide its inaccessible location makes it very difficult to repair. The lever float, sometimes used, has generally proved very unsatisfactory for sewage because rags are apt to collect on the lever and prevent its operation. As in the case just mentioned it is generally very difficult to reach such a float to repair or adjust it. The best design is one in which the float is arranged in a tube to guide and protect it and a removable cover plate provided over the tube so that the float can be readily lifted out.

[1]From a paper presented before the N. Y. State Sewage Works Ass'n.—1935.

[2]Senior Sanitary Engr., N. Y. Dept. of Public Works.

Pumps in Separate Dry Wells

For the larger pump stations, and even in the small stations when the conditions will permit, the installation of the pumps in a separate dry well makes the most satisfactory arrangement. This leaves the pumps and their appurtenances accessible for repairs and adjustment. The pumps may be either vertical or horizontal. The vertical pumps have the advantage of requiring a smaller pit and of keeping all electrical equipment above ground and free from danger of flooding, while on the other hand the horizontal pumps are easier to keep in adjustment and alignment. If the pit is deep, one or more guide bearings will probably be required on the shafts of vertical pumps as it is necessary to divide the shafts into lengths of not more than 8 or 10 feet to prevent vibration. I-beams are usually set across the pit to carry these bearings, but it is often difficult to set these beams so as to get a perfect alignment of the shaft. In order to avoid this difficulty, several manufacturers are building steel lattice frames extending from the motor to the pump. The pump and motor can then be aligned at the factory with very satisfactory results. In some cases the motor, shaft and pump have been attached to a heavy channel, aligned at the factory, and shipped as a unit.

With the pumps in a separate dry well it will usually be necessary to provide some means for removing seepage from the well. This may be done with a separate automatic sump pump, or, if a cheaper installation is desired, a small valved connection may be made from the suction of one of the main pumps to a sump and the sump emptied at intervals by closing the main suction valve and opening the connection to the sump.

Design of Suction Well

The shape of the bottom of the suction or wet well is of considerable importance. If it is left flat, solids will collect in the bottom and ferment giving rise to unsatisfactory conditions. The floor of the wet well should have a steep slope toward the pump suctions.

In some cases where the sewage is warm and contains considerable grease, trouble has been experienced due to the grease congealing on the walls of the well and then breaking loose in large pieces and entering the pumps and clogging them. The openings in the impellers of 4-inch horizontal sewage pumps have been stopped several times by this cause.

Bearings and Glands

There does not appear to be very much choice in regard to the type of bearings used, ball bearings and sleeve bearings seem to serve equally well provided they are properly oiled. Ball bearings are, however, usually provided to take the thrust or to carry the weight of the impeller of a vertical pump. The part of the shaft that passes through the stuffing box should be of bronze or covered with a bronze sleeve otherwise difficulty will be experienced in keeping the packing in condition. This stuffing box is usually provided with a water seal, although grease seals and special devices are sometimes used. In water pumps the water for the seal is usually taken from the volute of the pump. With sewage pumps, however, this is not advisable for the solids in the sewage are apt to clog the small passages and also because the grit in the sewage will reach the packing and cut the pump shaft. To avoid the possibility of the pollution of the clear water with sewage, the water must usually be taken from a constant level tank supplied from the water lines and not directly from the lines themselves. With double suction and open impeller pumps, if there is a suction lift, there will probably be vacuum on the pump side of the stuffing box and the water seal serves to prevent the entrance of air. With end suction pumps, with enclosed or semi-enclosed impellers, there may be a pressure on the pump side of the stuffing box. The water seal then serves to prevent the grit in the sewage from reaching the packing and cutting the shaft. The pressure on the water seal should of course be greater than the sewage pressure.

Centrifugal sewage pumps will operate satisfactorily if set as high as 15 feet or even a little more above the sewage level, but in such cases special priming devices must be provided for the ordinary method of priming, by filling the suction from the discharge line, cannot be used because it is inadvisable to attach a foot valve to the bottom of the suction. While special priming devices can be used, it is better, if possible, to locate the pumps below the level.

Efficiency and Head

The non-clogging centrifugal pumps will generally give over all efficiencies varying from 35 per cent for the smaller sizes to 65 per cent for the larger pumps. The lift of sewage pumps is usually low and most of the pumps are designed for heads under 40 feet but pumps can be obtained that will lift sewage against heads as high as 75 or even 100 feet. Beyond this head two stages are needed, but the ordinary type of multistage pump used for water cannot be used because of the many sharp turns and the narrowness of the water passages. At a station where it was necessary to raise sewage 180 feet, two pumps connected in series on the same base, with the motor between them, have been used successfully. The overall efficiency of the unit was found on test to be 35 per cent.

Hydraulic Characteristics of Centrifugal Pumps

With centrifugal pumps, careful attention must be given to the hydraulic characteristics of the pumps in designing a pumping station, particularly if the discharge line is of any considerable length.

If an engineer desires a pump to deliver 300 gallons per minute against a head of 20 feet he is very apt to add a little to the head for safety and specify that the pump shall deliver 300 gallons a minute against a head of say 21 feet. A typical 4-inch pump will meet these specifications almost exactly, and will require about 2¼ horsepower to operate it and, a 3-horsepower motor will serve satisfactorily. If, after installation, it is found that the actual head is only 18 feet instead of 21 feet, due to some unforeseen condition or due to the fact that the engineer figured his friction for 10 year old pipe and the pipe is actually new pipe, this pump will deliver 600 gallons per minute instead of 300 gallons per minute and will require 3½ horsepower. The 3-horsepower motor will in that case be overloaded. Conditions similar to this occur very frequently and it is best in all cases to require the motor to be of sufficient size to operate the pump without overheating at any head between the maximum and zero.

When two or more pumps are connected to the same discharge line, the reverse condition often occurs. If two pumps, having the characteristics mentioned above, are connected to a single discharge line, one pump operating alone will discharge 300 gallons per minute. When both pumps are put in operation the friction loss in the discharge line will of course increase. With the particular 4-inch pump just mentioned, if this increase is only about 1½ feet (from 21.0 feet to 22.6 feet) the discharge of each pump will be reduced to 200 gallons a minute or the total discharge of the two pumps will be about 400 gallons per minute or only slightly greater than the discharge of one pump. For this reason it is often found desirable, especially with long discharge lines, to arrange the controls so that one pump will shut off entirely and the second pump, designed for a larger capacity and a little higher head, will start when the sewage flow exceeds the capacity of the first pump.

Multispeed motors are sometimes used to meet these conditions but such motors operate only at certain fixed speeds and it is generally difficult to design the pumps to obtain the desired capacities at these motor speeds. Any desired speed may be obtained by using variable speed motors, but if this is done the losses in the resistances greatly reduce the overall efficiency of the pumping equipment.

At the Harlem Valley State Hospital pumping station which contains 8 4-inch 450 gallon per minute pumps, a special arrangement was used. As each additional pump starts the friction loss in the discharge line increases approximately 6 inches. The controlling float and float switches are so arranged that as each additional pump starts the sewage level in the suction well is automatically allowed to rise 6 inches. Thereby, the total head, and consequently the discharge of each pump, always remains the same and has proved a distinct advantage.

Suction Line Difficulties

There are several matters in connection with the arrangement of centrifugal pump suction lines, particularly where there is some suction lift, which, while they seem very simple, have caused engineers and operators considerable trouble. There must be no high point in any suction line where air or sewage gases may accumulate. When the pump is started the accumulated air will expand, flow to the pump, and stop its operation. The reducer at the pump must for this reason always be an eccentric reducer with the flat side up. Connections to a common suction header must for the same reason be made

at the top of the header and not at the center of the side. In some extreme cases it has even been found necessary to place the suction valves horizontally so as to avoid the accumulation of air in the bonnets. Common suctions, that is, single suction lines to which two or more pumps are connected, are a source of trouble in many cases where there is a suction lift, and wherever possible should be avoided. It is often difficult in such cases to make each pump take its share of the load. When one pump is in operation it is often impossible to start the second without shutting down the first and starting both together. A slight leak in the stuffing box of one of the idle pumps will many times admit enough air to interfere with the operation of the other pumps. Even when the pump that is not to be operated is entirely shut off, air will frequently accumulate in the riser from the common suction to that pump and will expand when the other pump or pumps are started and enter them and prevent them from operating.

Sludge Pumps

Both centrifugal pumps and reciprocating pumps have been successfully used for pumping sludge. Where the quantity of sludge is large, the centrifugal pumps with suitable non-clogging impellers are probably the more satisfactory. In many cases, such as pumping sludge from the bottom of a settling tank, it is desirable to draw the sludge slowly and regulate the rate carefully to prevent drawing the upper layer of fresh sludge, or even the supernatant liquid through the digested sludge in the bottom of the tank. Except in the largest sewage disposal plants this may be difficult with a centrifugal pump. If a small sized pump is used, it is apt to clog. If a large sized pump is used it will generally be necessary to decrease its capacity at times. Throttling the discharge of a sludge pump for this purpose is obviously undesirable. Motors with variable speed transmissions by means of which the pump speed may be varied without varying the motor speed, while rather expensive, may be used very satisfactorily for this purpose. Centrifugal sludge pumps must of course be set below the water level in the suction well if priming difficulties are to be avoided.

For the above reasons the reciprocating pump is probably better adapted for sludge pumping in small sewage disposal plants. Where the lift is high and it is not necessary to vary the capacity, the ordinary single acting triplex pump, with ball valves, has proved very satisfactory. Where the lift is low and it is necessary to vary the flow, as is usually the case, the diaphragm pump or the plunger pump with large diameter cylinders, designed especially for handling sludge, is usually preferable. The present tendency seems to be toward the use of the plunger pump in preference to the diaphragm pump. At the Hudson River State Hospital sewage disposal plant, where the 10-inch diaphragm pumps are used about three hours daily, the diaphragms have to be renewed every six months.

On the other hand, at this same plant, where 10-inch plungers are used, the packing, under continuous operation, has to be renewed every three months. These pumps may have one or more cylinders. The pumps with two or more cylinders give a more even discharge and also a more nearly even load on the motor, but the single cylinder pumps serve satisfactorily in most cases. Where lime is fed into the pump suction the surge in the suction line caused by the single cylinder pump sometimes causes trouble. Different capacities may be obtained with these pumps by varying the length of the stroke. This is done on some pumps by using an eccentric on the main shaft which is adjustable to give any stroke from zero to the maximum. On the other pumps several holes are provided in the crank so that the stroke may be changed by inserting the connecting rod pin in the proper hole. In some cases two and three speed motors have been provided with pumps of this type to further increase the possible number of capacities. The stroke of a diaphragm pump can generally be varied from 0 to 3 inches while that of a plunger pump can generally be varied from 2 to 5 inches. Shear pins are usually provided to release the motor should any hard material stop the plunger. It is well to keep the speed of reciprocating pumps rather low if smooth operation is desired. Speeds of over 30 or 35 revolutions per minute will usually cause vibration although manufacturers often recommend higher speeds. The valves may be of the ball or of the flap type. The ball valves usually show less tendency to collect solids than the flap valves, but are not entirely free from clogging. Rags will pack under the balls and sometimes clog the valve chamber entirely. Special easily removable caps are generally provided on the valve chambers so that the valves will be readily accessible for cleaning. In this connection it might be well to note that if an air chamber, or alleviator, is provided on the discharge line the discharge shut off valve should be between the air chamber and the pump or a special drain valve provided for the air chamber. Otherwise the sludge in the air chamber will be blown out through the discharge valve chamber when the cap is removed for cleaning or repairs. Pumps of the reciprocating type need not be set as low as centrifugal pumps because they prime more readily.

Friction of Sludge in Pipe

Where the suction and discharge lines are long it is often necessary to consider the friction loss in the pipes when the sludge is passing through them. Considerable has been written on this subject but there is as yet no standardized formula for computing the loss. The loss for a sludge with a high water content is about the same as for water but increases as the water content decreases until it often reaches 1½ times the loss for water. The loss is sometimes figured by using a coefficient of 60 or 70 in Chezy's formula instead of the 100 usually used for water.

Motive Power

At the present time most pumps are driven by electric motors. It was customary a few years ago to provide auxiliary gasoline engines as a source of power when the electric power failed. Usually, however, when the electric current failed, the service was restored before the operator could start his neglected gasoline engine. With the use of underground transmission lines and inter-connected power stations, failure of electric current has been so reduced that the auxiliary engines are now being omitted in most stations. Gasoline engines, oil engines and steam engines can, however, be used satisfactorily for driving pumps where electric current is not available.

OPERATING CONTROL TESTS FOR THE ACTIVATED SLUDGE PROCESS

By T. R. HASELTINE†

Superintendent of Sewerage, Butler, Pa.

The first requirement of the activated sludge process is the maintenance of dissolved oxygen in the aeration tanks. As early as 1926, Harris, Cockburn and Anderson[1] stated this principle of the process very clearly. Their work proved that "the dissolved oxygen adsorbed by the sludge is a constantly decreasing amount from its contact with the inflowing sewage to its discharge from the reactivation channels. The *starting point* of the process of reactivation may be accepted as the point nearest the inflow of the aeration tank at which dissolved oxygen first appears. The degree of reactivation that takes place in the aeration tank is dependent upon the balance maintained between the supply of, and the demand on, the dissolved oxygen and the period of detention as timed from the determined starting point."

Every operator of an activated sludge plant must know that the process is dependent upon aerobic bacterial action. Therefore, it should be evident to all that the presence of dissolved oxygen in the aeration tanks is a prime requisite for the proper functioning of the process. In spite of its self-evident nature some operators may lose sight of this principle of the process, due perhaps to their efforts to comprehend and apply the never-ending stream of articles dealing with the relative merits of pH control, various types and designs of structures and equipment, or the use of chemicals as an adjunct to the process. It is, therefore, very refreshing to read Mr. Anderson's timely and extremely logical articles[2, 3, 4] on the operation and control of the Rockville Center activated sludge plant. It was those articles that led the writer to prepare the following discussion for publication in WATER WORKS AND SEWERAGE that carried Mr. Anderson's two articles.

"Tapered Aeration"

The "tapered aeration" effect while not new in principle, is worthy of far more widespread application than it now receives. The writer operated the Salinas, California, plant[5] from 1930 to 1933. During that time we found, after extensive experimentation, that the best results were obtained by so adjusting the air distribution that (a) there was an appreciable amount of dissolved oxygen in the sludge reaeration compartments, (b) there was at least a small amount at the inlet of the aeration compartments, and (c) the dissolved oxygen gradually increased towards the outlet of the aeration compartments. This required the use of from 55 to 70 per cent of the total air applied in the first half of the aeration tanks. The percentage increased some with high sewage flows, low air supplies, or bulked sludge and visa versa.

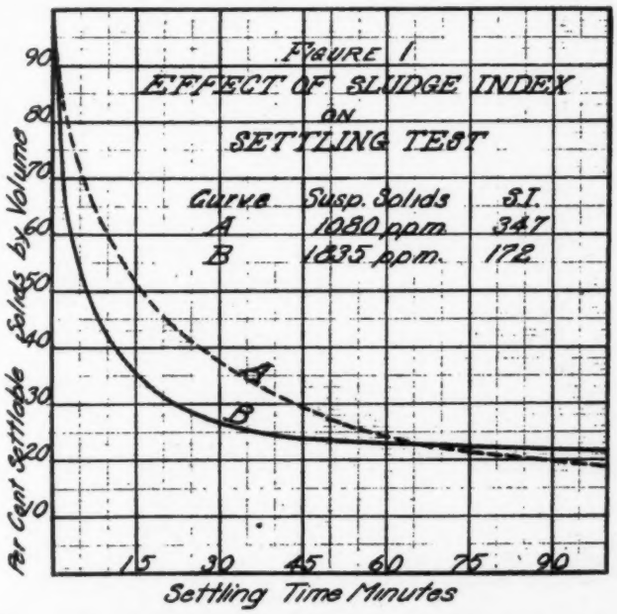


Fig. 1.—The Effect of Sludge Density (Sludge Index) on the Volumetric Sludge Settling Test.

Dissolved Oxygen Tests

To maintain "tapered aeration" it is, as Mr. Anderson points out, necessary to make frequent dissolved oxygen (D.O.) determinations throughout the aeration tanks. However, the writer marvels at the success of Mr. Anderson[4] in using the regular Winkler method for such determinations; first, because one would expect interference from nitrites and, second, because it has been our experience that the sludge floc adsorbed some of the reagents and masked the end point of the titrations. We doubt if the operators of many activated sludge plants would find the regular Winkler method satisfactory. The Report of the Committee on Methods of Sewage Analysis[6] states that "as a rule nitrites will occasion erroneously high results when present in amounts exceeding 0.1 p.p.m. of N. as nitrite. Interference due to nitrites may be expected in dealing with effluents from biological oxidation devices." Whenever the presence of nitrites is suspected the report recommends the use of the permanganate modification of the Winkler method. At Salinas our crude sewage had an organic-plus ammonia nitrogen content of about 65 p.p.m. Our final effluent usually contained from 0.2 to 3.0 p.p.m. of nitrite nitrogen. As might be expected we found the regular Winkler method valueless under such conditions; in fact, we had to use a double strength permanganate solution much of the time.

The accurate determination of the dissolved oxygen in the mixed liquor of the aerators is extremely difficult and requires special apparatus such as was devised by Theriault and McNamee.[7] They state that the usual technique of working only on supernatant liquor from settled sludge gives low results (not subject to empirical correction) due to the high oxygen demand of the sludge itself. However, the writer believes that with proper care it is entirely permissible (for routine plant control) to work on a supernatant liquor and thus avoid the complications of sludge floc or the use of special equipment. It is always desirable to have a margin of safety in plant operation and the errors pointed out by Theriault and McNamee are on the side of safety.

At Salinas we collected samples of mixed liquor from various points throughout the aerators in 2 liter bottles. The bottles were completely filled, stoppered and allowed to stand until 270 m.l. of fairly clear supernatant liquor could be siphoned off into small bottles. The permanganate modification of the Winkler method was then used to determine the dissolved oxygen content of these smaller samples. Ordinarily 5 to 15 minutes' standing of the 2 liter samples would result in sufficient clarification although at times of severe bulking as much as 40 minutes elapsed before the small samples could be siphoned off. On several occasions we siphoned off a second small sample an hour or two after taking the first one and repeated the D.O. determinations. The decrease in dissolved oxygen in the supernatant over the elapsed time was surprisingly small even though the liquor had been underlain by sludge all that time.

Second Operating Requirement

The necessity of maintaining an adequate supply of dissolved oxygen in the aerators at all times, when coupled with the desirability of keeping the power expenditure for aeration at a minimum, leads directly to the second operating requirement—namely, that of keeping the oxygen demand of the mixed liquor at a minimum. The oxygen demand of the mixed liquor is in part due to that of the sewage and in part due to that of the sludge. However, that of the sludge is so much the greater, that of the sewage becomes almost negligible. Grant, Hurwitz and Mohlman[8] proved in the laboratory that (a) mixtures of sewage plus sludge absorb oxygen in proportion to the weight of sludge but with increasing amounts of sludge most of the oxygen demanding material of the sewage is coagulated or adsorbed by the sludge so that very little oxygen is required for the unadsorbed material, and (b) small amounts of sludge reduce the B.O.D. of the sewage almost as rapidly as do larger amounts. Their findings have since been proven in many full scale plants.

It is, therefore, the problem of the operator to first determine

*From WATER WORKS AND SEWERAGE.

†With Chas. A. Haskins, Consulting Engineer, Kansas City, Mo., when this article was prepared.

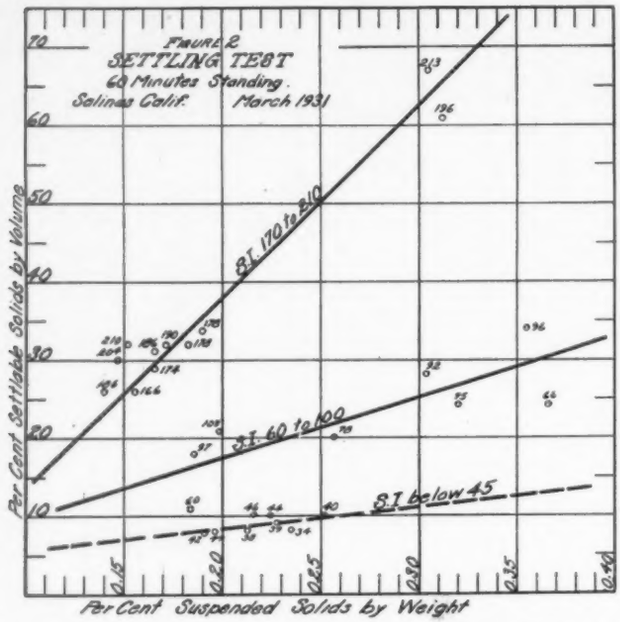


Fig. 2.—A Picture of the Lack of Correlation Between Volumetric Sludge Test and the Gravimetric Test. The Necessity of Taking into Consideration the Density and Settleability (Sludge Index) Is Clearly Evident.

the minimum *weight* of sludge that it is necessary to carry in his own individual plant and then, second, to so control the rate of sludge return that that minimum amount is never greatly exceeded. To solve that problem it would be desirable to have some rapid and accurate means of approximating the *weight* of solids in a given volume of mixed liquor or return activated sludge. As yet no universally satisfactory method of making this determination has been devised. Three methods that have been more or less generally used are (a) settling tests, (b) suspended solids determinations, and (c) centrifugal tests.

All have their disadvantages.

Settling Tests

These are the simplest tests and were the earliest tests used. Samples of sludge or mixed liquor are simply collected in liter graduates, allowed to stand for some given time, and the per cent of settleable solids observed at the end of the given time. In the early days it was usually customary to carry about 20 per cent sludge, after 30 minutes standing, in the mixed liquor. The test is still used and is quite helpful so long as its limitations are kept in mind. Various standing times are used ranging from 10 minutes to 1 hour.

Attempts to correlate the volume of settleable solids, as determined in this way, with the actual weight of the suspended solids in the sample soon showed that no such relationship existed unless the sludge index[9] was also taken into consideration, see Figure 2. "The sludge index (S.I.) is the volume in cubic centimeters occupied by 1 gram of sludge solids after settling 30 minutes." The longer the settling test samples are allowed to stand, i.e., the more the sludge compacts, the less the influence of the S.I. on the results of the test and hence the closer their approximation to the actual weight of sludge solids present. Figure 1 illustrates this point fairly well. However, the rate of sewage inflow to the aeration tanks is constantly changing and tests to regulate the amount of return sludge must be rapid if the weight of sludge solids returned is to be varied in accordance with the sewage flow.

In general the settling test alone can not be relied on except in the smallest plants, and even then only in those small plants that are so amply designed that they are subject to little bulking. In such plants the possible saving in power may not be great enough to warrant the added cost of conducting more accurate test methods.

Suspended Solids Determinations

Suspended solids determinations are the only accurate means of determining the actual *weight* of sludge solids in a given sample of mixed liquor or return sludge. Unfortunately so much time is required for making the determinations that the test is useless as a means of coordinating the hourly rates of addition of sludge solids with the hourly rates of sewage inflow to the aerators. In spite of this handicap the test is extremely valuable and should be made at least once a day at all but the very smallest plants. It should be made at the same time each day; the time selected should be such that the sewage flow for the past several hours has been nearly identical with that of the same hours of each preceding day.

For example, at Salinas[6] we took samples for suspended solids determinations each day at 9 a. m., there being only slight day to day variations in the hourly rates of flow received at that plant between 2 a. m. and 9 a. m. We governed the daily amount of activated sludge wasted almost entirely by the results of these determinations. (The rate of sludge withdrawal from the clarifiers was governed by hourly determinations of the depth of sludge in them. We attempted to keep the rate of withdrawal as low as possible without permitting more than a 1-foot depth of sludge at the sides of the Dorr tanks.) This procedure did *not* accomplish the very desirable end of keeping the suspended solid content of the aerators constant at all times throughout the day. It was probably at a minimum about 11 a. m. when the peak flow started coming in and at a maximum between 10 and 11 p. m. when the flow started dropping off rapidly. However, it did serve to keep the *average daily* suspended solid content of the aerators fairly constant.

Before leaving the subject of gravimetric solids determinations the writer wishes to make a plea for all operators to base their control on *suspended* solids determinations rather than on *total* solids determinations. It is the suspended solids in the sludge that exert the bulk of its oxygen demand. It would be permissible to base plant control on total solids determinations only if the dissolved solids were practically constant. Such is not the case—at Salinas,[6] dissolved solids in the mixed liquor, and plant effluent, ranged from 600 to 1500 p.p.m. under varying sludge conditions.

Centrifugal Tests

This test consists of collecting samples of mixed liquor or sludge in 15 m.l. centrifuge tubes and "spinning" them for a given short time (2 to 5 minutes) in an electrical centrifuge. A hand centrifuge will not serve because of the impossibility of always spinning the samples at the same speed. The writer first heard of this test being used at the Indianapolis plant some eight or nine years ago. We tried it for several months at Salinas. Mr. Anderson[2, 3, 4] has recently reported its successful use at Rockville Center. The test has probably been used at several other plants but it has never been widely adopted. To the writer's knowledge, Mr. Anderson is the first to mention it in the literature.

Like the settling test, the centrifugal test is at best volumetric determination. Nevertheless, it has two outstanding advantages over the gravity settling test. (a) It is extremely rapid and so

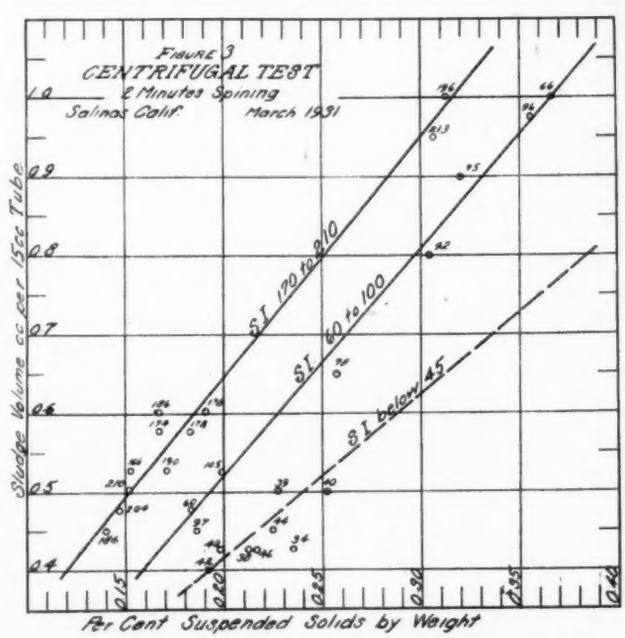


Fig. 3.—A Picture of the Less but Evident Effect of Sludge Index Values on Suspended Solids Tests With the Centrifuge.

may be utilized, with reservations, to control the hourly rates of sludge withdrawal or return. (b) It compacts the suspended solids more and hence there is better correlation between its results and those of gravimetric suspended solids determinations. However, even the results of this test are greatly influenced by the sludge index as is clearly shown by Figure 3. If that fact is not fully appreciated the operator may encounter serious complications in attempts to regulate *weight* of suspended solids in his aerators.

If the test is to be used the operator should first make sufficient trials to prepare a graph similar to Figure 3. Once such a graph is available he may determine the sludge index once a day and from that determination and the graph he can select the desirable centrifugal test results for the more frequent determinations made on the mixed liquor, return sludge, etc.

To substantiate this assumption we submit Table I. Sample 6 was a sample of the return sludge from the Salinas plant; samples 1 to 5, inclusive, were prepared by diluting sample 6 with varying amounts of final effluent that had been collected at the same time.

TABLE I

Sample	Suspended Solids % by weight "A"	Settleable Solids % by volume 30 min. standing "B"	Sludge Index (B/A)
1.....	0.064	5	78.1
2.....	0.172	15	87.2
3.....	0.289	25	87.2
4.....	0.400	35	87.5
5.....	0.549	50	91.1
6.....	1.078	100	92.8

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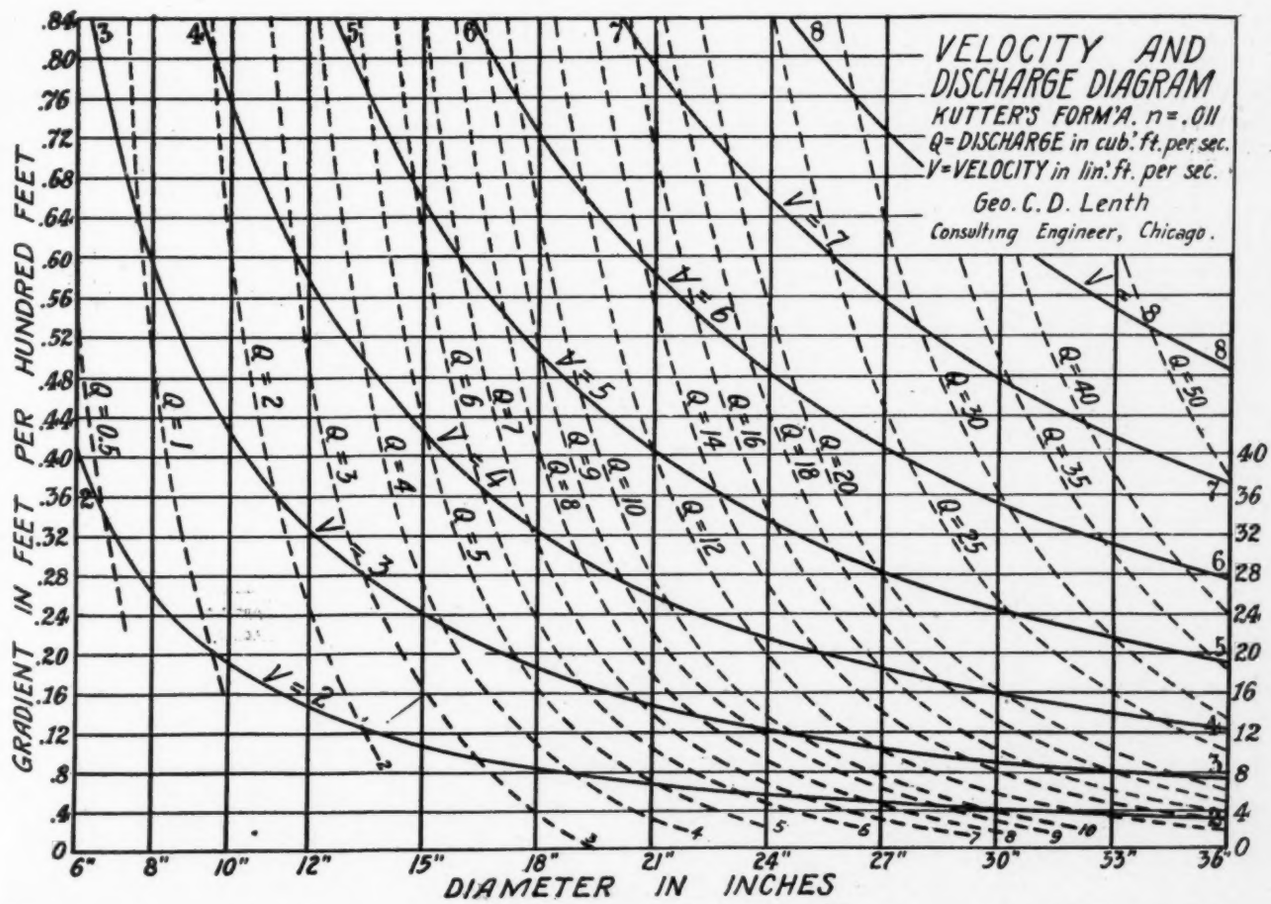
Velocity and Discharge Diagram for Vitrified Clay Sewer Pipe

(Courtesy, Clay Products Assn.)


VELOCITY AND DISCHARGE DIAGRAM
KUTTER'S FORM'A. n=.011
Q=DISCHARGE in cub'. ft. per sec.
V=VELOCITY in lin'. ft. per sec.
Geo. C. D. Lenth
Consulting Engineer, Chicago.
GRADIENT IN FEET PER HUNDRED FEET
DIAMETER IN INCHES
6" 8" 10" 12" 15" 18" 21" 24" 27" 30" 33" 36"

(Example: Assume 12 cu. ft. per sec. as the flow to be handled. The gradient for instance, to be a 0.2 ft. per 100 ft. run. Follow to right from gradient figure .20 on left until Q12 dotted line is intersected. The vertical line found at that point indicates that a 24 inch sewer is required. Also from the nearest velocity curve V.4 at the intersection it is revealed that the velocity will be 3.8 ft. at full or half full flow.)

SLUDGE BLANKET DETECTOR AND TURBIDIMETER

By DON E. BLOODGOOD

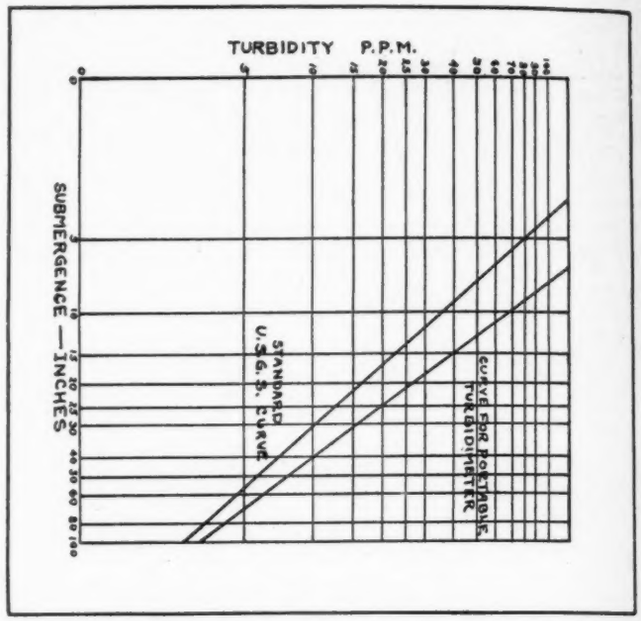
Engineer, Sanitation Plant, Indianapolis. Ind.

To a sewage plant operator, the appearance of the effluent is the best indication of the effectiveness of the treatment process. But to convey to the superintendent an accurate description of the appearance, in writing, is difficult. A superintendent should know each morning the hourly condition of his plant during his absence. He also wants his operators to be able to tell him how one day's effluent compares with that of any other day.

To supply this information in the most concise, yet explicit form, an instrument has been constructed at the Indianapolis Sewage Treatment Works which can be used as a portable turbidimeter and a sludge blanket detector. It consists of an 1¼ inch I.D., 0.065 wall, 2 FH aluminum tube 68 inches long with a sleeved brass collar on the bottom into which the brass moisture proof lamp case screws. There are four ports in the cap which admit water but exclude all outside light. The glass disk is held against a rubber gasket making a water tight joint. In the 1/32 inch metal disk there is cut a ¾ inch cross of 0.012 inch opening with the center closed off by a piece of metal not larger than 3/32 inches in diameter to blank out the bright spot caused by the bulb filament. The light reflector is painted with aluminum paint. The operation of the lamp is identical with the ordinary two cell flashlight except for the self-operating mercury switch. • This mercury switch is in the base cap of the lamp case and is constructed in a case of sealing wax. The sealing wax was first run into the base cap and sloped to a small depression in the center. A short piece of No. 24 platinum wire was set on each of opposite sides of the depression with the ends about ⅛th of an inch apart. One wire is grounded to the base cap and the other is connected to a copper plate, making a connection with the battery through the coil spring. Only a very small drop of mercury is needed in the switch. After the mercury is placed, a heavy paper disk is set over the top of the mercury pocket and the cap is filled with sealing wax.

In use, the instrument is submerged to a point at which the cross disappears and then the scale on the side of the tube is read by looking in to the six-sided mirror of the float, in one plane of which the figures will show. The mirrors are set at a 45° angle with water proof china cement in sycamore or any other tough light wood.

The portable turbidimeter was calibrated by getting the submergence in effluents of known turbidity. This data when plotted on logarithmic paper gave a curve somewhat different than did the data of the standard U.S.G.S. turbidity table, as can be seen by the accompanying graph. The scale for any turbidimeter constructed could be obtained from the graph of the calibration data



Graph for Converting Submergence Into Trubidity Reading

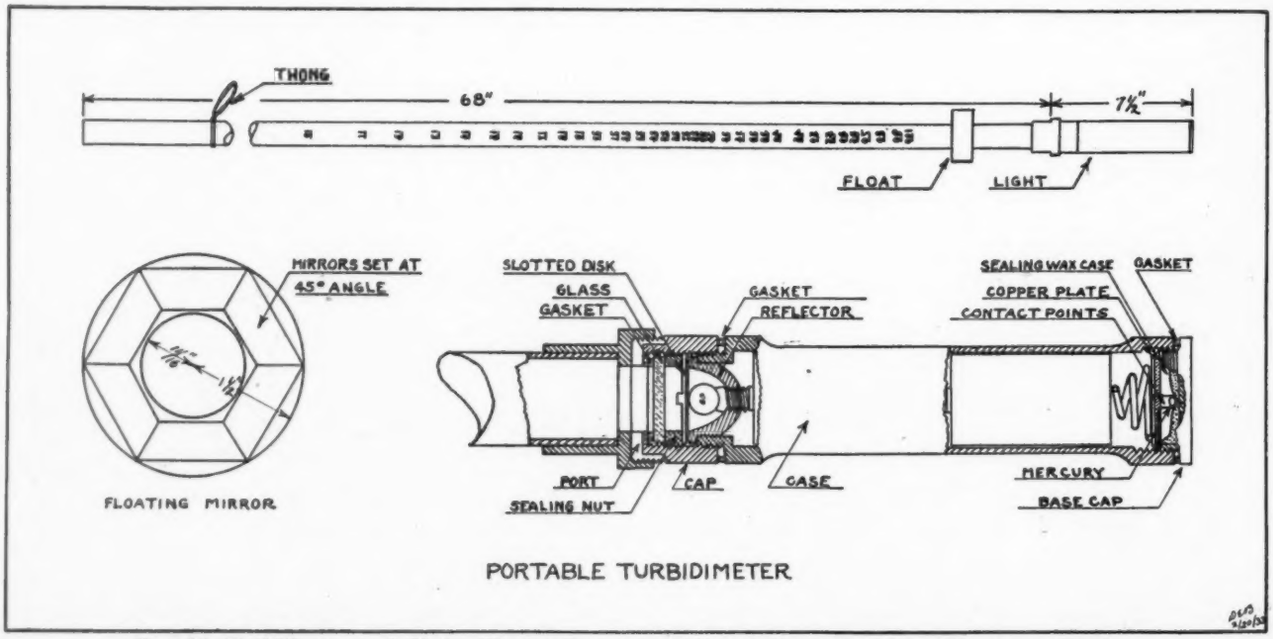
or it could be calculated by developing a formula for the particular curve, similar to the formula of the standard curve:

$$\log y = -1.106598 \log X + 2.6570$$

in which y= p.p.m. of turbidity and X = submergence in inches. The curve for the portable turbidimeter herein described is:

$$\log y = -1.35652 \log X + 3.2085$$

The shortcomings of the portable turbidimeter are appreciated. The turbidity increases at lower levels of the basin so that the readings obtained may not describe the nature of the actual effluent and yet be indicative of plant operation. At Indianapolis, however, the information obtained through the use of the portable immersion turbidimeter has been very helpful in connection with plant operation.



Portable Turbidimeter and Sludge Blanket Detector Used at Indianapolis Sewage Treatment Works

ACTIVATED SLUDGE THICKENING*

By D. TRAVAINI

Superintendent, Sewage Treatment Works, Phoenix, Ariz.

Phoenix, Arizona, has an activated sludge plant with Dorrco aerators, and utilizes separate digestion of mixed crude sludge solids and the wasted activated sludge. C. C. Kennedy, Consulting Engineer, who designed the plant, provided a sludge thickener for the purpose of concentrating activated sludge.

The sludge thickener, as constructed, is a circular tank 35 ft. in diameter with an effective depth of 9 ft. at the periphery of the tank with 1 ft. of free board above the water level. The thickening mechanism was supplied by the Dorr Company and consists of a picket fence made of 2-in. pipe on 6-in. centers extending 5 ft. above the bottom of the tank floor. This is attached to the bracing supporting the bottom scrapers. A skimming arm is also provided. See Fig. 1.

The tank is centrally located and arranged so that waste activated sludge, mixed liquor, plant effluent, primary sludge, or digester overflow liquor can be admitted through pipe inlets at one side of the tank, approximately 18 ins. below the water level.

*Excerpts from an article appearing in WATER WORKS AND SEWERAGE, April 1934.

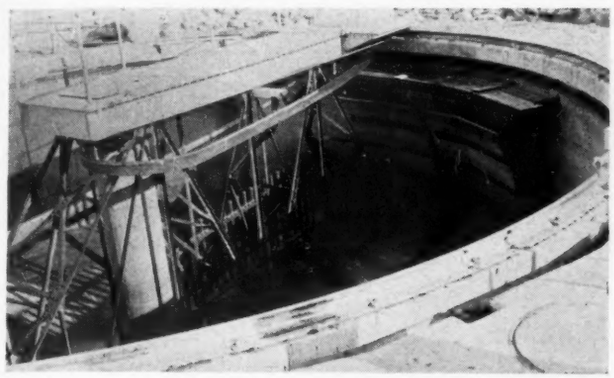


Fig. 1—Thickener Mechanism Showing Picket Fence Bottom Scrapers and the Sacramento Type Inlet Baffle

Fig. 2—Sacramento Baffle and One of the Three Chlorine Hose Inlets

A 24-in. redwood baffle 13 ft. long was provided in front of the pipe inlets.

The original baffle at the inlet was not satisfactory. Short circuiting was so pronounced that it prevented effective utilization of the tank capacity. After considerable investigation, a Sacramento baffle was installed in May, 1933, and ended the short circuiting troubles. We attribute the successful use of the thickener to this baffle and the installation of a Wallace and Tiernan chlorinator made at the same time, the value of which will be discussed later. Before these improvements were made we were prone to look upon the thickener as a liability rather than an asset.

The Sacramento type baffle was developed under the direction of Professor Charles Gilman Hyde more than ten years ago. The structure built at Phoenix consists of a redwood baffle 24 ins. from the wall at the water surface, tapering to 9 ins. at the wall 36 ins. above the intersection of the vertical wall and sloping bottom. This baffle is perforated with 4-in. square openings on 18-in. centers, both ways. Nine inches in front of these openings

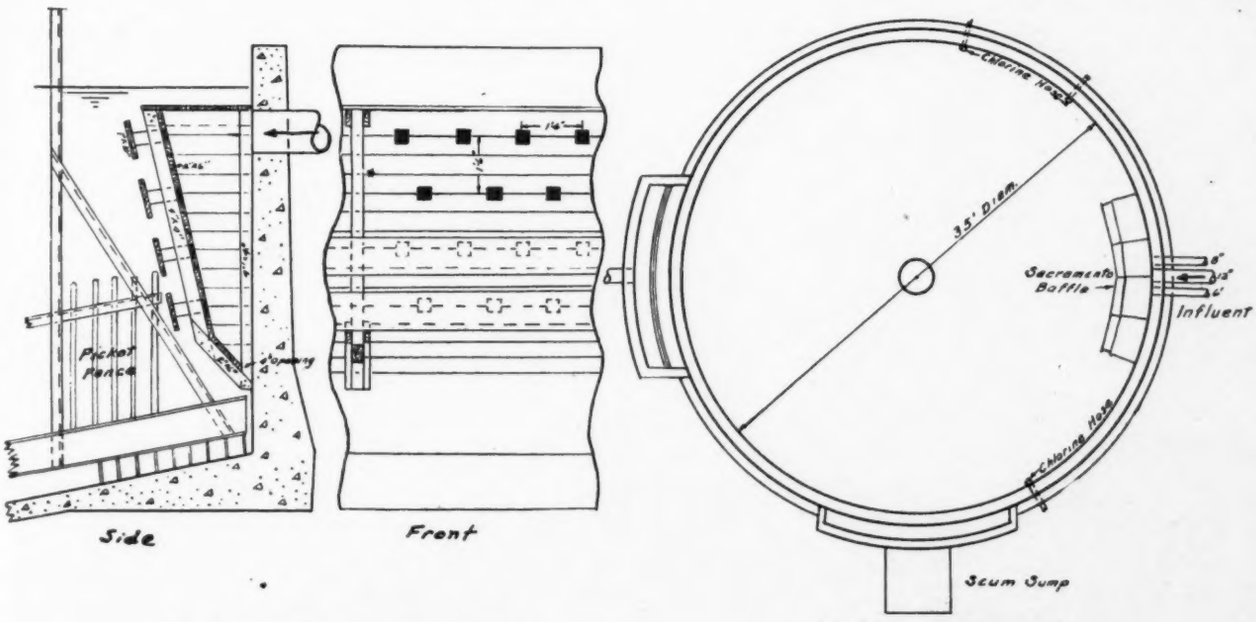


Fig. 3—Detail of Sacramento Baffle and Plan of Thickener, Showing Location of Baffle and Points of Chlorine Application

TABLE 1—RETURNED SLUDGE AND MIXED-LIQUOR (SLUDGE) THICKENING DATA. (RESULTS REPRESENT 24-HR. COMPOSITE SAMPLING.)

Date	Gals. of mixed liquor wasted	Chlorine #/24 hrs.	Influent (Mixed Liquor)				Effluent				Thickened Sludge	
			pH	% by volume 1 hr. settling	Suspended Solids p.p.m.	Suspended Solids % dry wt.	Total Solids p.p.m.	Suspended Solids p.p.m.	B.O.D. p.p.m.	pH	% Solids dry weight	pH
1/18/34	144000	35	7.6	30	1620	0.162	1075	21	20	7.6	—	—
1/19/34	144000	35	7.6	42	1725	0.172	1007	31	24	7.6	4.021	7.6
1/20/34	132000	35	7.8	50	1823	0.182	1012	31	28	7.8	4.287	7.8
1/21/34	144000	35	7.8	55	1342	0.134	1000	16	38	7.8	3.937	7.8
1/22/34	132000	30	7.6	50	1865	0.186	938	42	36	7.6	3.571	7.8
1/23/34	234000	45	7.6	47	2339	0.234	1020	26	26	7.6	4.120	7.6
1/24/34	288000	53	7.6	42	1618	0.162	1074	37	46	7.6	4.090	7.6
1/25/34	207000	50	7.6	54	2232	0.223	1015	26	32	7.6	3.529	7.6
1/26/34	132000	50	7.6	40	1065	0.106	1045	13	16	7.6	3.996	7.6
1/27/34	172000	41	7.6	32	1255	0.125	909	38	30	7.6	3.827	7.6
1/28/34	158400	40	7.6	30	1863	0.186	1010	27	22	7.6	4.090	7.6
1/29/34	158400	36	7.8	28	1652	0.165	995	13	16	7.8	3.684	7.8

Date	Gals. of returned act. sludge wasted	Chlorine #/24 hrs.	Influent (Returned Activated Sldg.)				Effluent				Thickened Sludge	
			pH	% by volume 1 hr. settling	Suspended Solids p.p.m.	Suspended Solids % dry wt.	Total Solids p.p.m.	Suspended Solids p.p.m.	B.O.D. p.p.m.	pH	% Solids dry weight	pH
2/9/34	70500	60	7.6	98	5243	0.524	1210	36	106	7.6	—	—
2/10/34	60300	65	7.8	88	5651	0.565	1163	43	126	7.8	3.618	7.8
2/11/34	45200	65	7.8	99	6920	0.692	1090	28	95	7.8	3.684	7.8
2/12/34	38500	55	7.8	99	7848	0.785	1215	45	152	7.8	3.262	7.8
2/13/34	54100	55	7.8	98	8132	0.813	1230	52	166	7.8	4.127	7.8
2/14/34	19200	50	8.0	98	7337	0.734	1140	38	120	8.0	4.006	8.0
2/15/34	30300	35	7.8	98	8243	0.824	1125	45	138	7.8	3.529	7.8
2/16/34	11040	40	7.8	98	9130	0.9130	1110	32	95	7.8	3.280	7.8

Note:- Results from 24 hr. composites.

are suspended wooden baffle boards 10 ins. wide. See Figs. 2 and 3.

Operation of Thickener

Since the plant was first placed in service on March 15, 1932, the thickener operation has been diversified. We have used this structure to concentrate primary sludge, wasted activated sludge, combined primary sludge and wasted activated sludge, waste mixed liquor, combined primary sludge and waste mixed liquor, and digester overflow. The results obtained varied considerably and with some of the operations odor nuisance became a serious problem. The use of the thickener was, for the time being, abandoned.

On June 2, 1932, activated sludge had built to a point where wasting could proceed, and the thickener was again placed in service. We were unable, however, to hold the sludge in the thickener sufficiently long to obtain the degree of concentration anticipated when the tank was designed. When we attempted to hold it to increase the solid content to the point anticipated, the sludge would rise and odors became pronounced.

Attempts to Control Septicity and Short Circuiting

In the early part of October, 1932, we arranged to return plant effluent to the thickener, hoping that the dissolved oxygen in the effluent would retard septic action and thus eliminate odors and allow a longer sludge holding period. This procedure aggravated the short circuiting in the tank and caused the solids in the effluent to increase materially.

The short circuiting in the thickener made it apparent that the original baffle was not efficient and resulted in the installation of the Sacramento baffle. We also installed a Wallace and Tiernan solution feed chlorinator in order to use liquid chlorine to retard septic action. With the chlorinator we anticipated accurate control of chlorine applied to the thickener, which was not

TABLE 2—SLUDGE CONCENTRATION DATA

	Depth from liquid level in ft.	Nov. 3 1933	Dec. 11 1933	Jan. 20 1934	Feb. 11 1934
% Solids in sludge at depth shown	3	—	0.25	0.27	0.810
	4	0.50	0.50	0.70	1.02
	5	1.20	1.05	1.15	1.35
	6	1.04	1.25	1.37	1.72
	7	1.20	1.40	1.55	2.38
	8	1.40	1.70	2.10	2.87
	9	3.50	3.25	3.75	3.05
	Cone	4.08	4.21	4.28	3.68
% Solids in sludge—Influent		0.105	0.195	0.182	0.692
pH - Influent		7.8	7.8	7.8	7.8
pH—Thickened Sludge.		7.6	7.8	7.8	7.8
Suspended Solids p.p.m. - Effluent		20	25	31	28
B.O.D. - p.p.m. Effluent		—	30	28	95

Note:- Results from 24 hr. composites.

possible under the crude conditions in which we had been using lime and chloride of lime earlier.

We devoted our spare time to experiment, to determine the efficiency of the baffle and to find at which points to chlorinate the sludge input in order to obtain the best distribution of chlorine. The results obtained from the baffle were very gratifying. By the trial and error method we selected three points of application of chlorine that gave the best distribution. The chlorine hoses are submerged 3 ft. below the liquid level in the tank. One point of application is 13 ft. along the periphery of the tank from the west end of the baffle. The other two points are 9 ft. and 18 ft., respectively, along the periphery of the tank from the east end of the baffle.—See Figs. 2 and 3.

By varying the quantity of chlorine solution applied at the points mentioned even distribution of chlorine was maintained in the surface liquor, where desired, rather than in the sludge proper.

With this preliminary work completed, during the early summer we tried concentrating primary sludge in combination with mixed liquor taken from the aeration tanks; then primary sludge with returned activated sludge, and then returned activated sludge alone. Very good results were obtained in each instance, but the trials with mixed-liquor seemed the best.

The Scheme That Gave the Best Overall Results

In August, 1933, we decided to try concentrating mixed liquor only, a method suggested by R. F. Goudey.[1]

Our object was, that in summer the primary clarifier influent is stale and we felt that by adding to the crude sewage a sizeable flow of effluent from the thickener, containing dissolved oxygen and some residual chlorine, it would improve plant operating conditions. The amount of thickener effluent would naturally be much greater when concentrating sludge from mixed liquor than when concentrating returned activated sludge and therefore the greater benefit to the crude sewage.

The results obtained by thickening mixed liquor taken from the aeration tanks were so satisfactory that we soon adopted it as routine operation. The primary sludge is concentrated to approximately 5 per cent in the primary clarifier and is mixed with the thickener sludge by pumping sludges from both tanks simultaneously to the digesters.

In Table No. 1 analytical data of thickener operations are given for mixed liquor and also when "returned" activated sludge from the clarifier was treated. Table 2 shows the solids content of the sludge at various depths. As a result the installation of the Sacramento baffle and chlorination, we can maintain a clear overflow with the sludge blanket within 3 ft. of the liquid level, when wasting 200 gpm. or less of mixed liquor or returned sludge through the thickener. The costly chlorination is considered very nominal considering its advantages.

Conclusions

Since we installed the Sacramento baffle and eliminated short circuiting, and since we started to chlorinate the top liquor to retard bacterial action and thereby control septicity, the thickener has operated satisfactorily and accomplishes the purpose for which it was designed, viz.: reducing the volume of sludge and hence the volume of supernatant liquor which is so disastrous to the activated sludge process. Likewise the need for greater digester capacity.

[1]"A New Method of Concentrating Activated Sludge," R. F. Goudey and S. M. Bennett. WATERWORKS AND SEWERAGE, May, 1933.

NOTE—This scheme of sludge concentration has since been adopted at other activated sludge plants—notably Lancaster, Topeka, Baltimore, New York City.]

"Dry Cleaning" Air Diffuser Plates

By A. M. RAWN

Associate Editor, Los Angeles, Calif.

Every once in a while someone does something that makes one stop and wonder why it has never been done before. Or, if ever done, why he has not heard of it.

Maybe you have been in Southern California when, due to "unusual weather conditions" the winter temperature drops below freezing and the citrus growers start the orchard smudge-pots, to warm up the whole outdoors and keep the crops from freezing. If you have, you may recollect that upon such occasions the air in the orchard areas is so filled with thick, oily smoke that one cannot see a hundred feet. This winter has been such a one and for a number of days early this month (January) millions of gallons of oil have been burned in the smudge-pots.

Now this may not seem to have anything to do with sewage disposal, but strangely enough it does have.

The city of Ontario lies right in the heart of the citrus grove area and, in consequence, was encompassed in a dense smoke fog for some time. During this period the operator of the Ontario activated sludge plant noticed that the pressure on the air lines was steadily increasing at the blowers. Attributing it to the oily carbon in the air, as most likely responsible for the clogging of the diffuser plates, he made every effort to cleanse the air by straining it through several thicknesses of cloth over the air inlet to the blowers. The cloths were changed frequently but to no avail. And, pressures at the blower mounted from 5 to 7½ pounds over night.

Obviously the diffuser plates, which had operated for more than a year with no building up of pressure, had to be cleaned. The finely divided carbon and oil in the smoke had doubtless spread quite uniformly through the plate pores. The orthodox manner of cleaning would have been to remove the plates and clean them up with a solvent and, if not successful, burn out the volatile materials, possibly. The city engineer had other ideas, however, and instead of bringing the plates to the solvent the solvent was taken to the plates. A scheme for injecting the solvent into the air stream from the blowers was put into operation.

What was actually done was to slowly pump "Aviation" grade of gasoline into the air line and beyond the blower. Two gallons of gasoline was fed into the pipe slowly during a 24-hour period. It did the job all right, because during this period pressures dropped back to normal and the trouble was completly cured. So far, there has been no injurious effect upon the quality of the plant effluent or the behavior of the sludge.

This struck the writer as being a most unique method of overcoming a serious difficulty. Mr. Austin Burt, Ontario's city engineer, was "the brains" behind this "solvent-solved situation"; and H. M. Ely, as chief operator of the plant, was "the brawn."

In his latest advice to the writer the "inventor" of diffuser dry cleaning states: "We have had to apply our gasoline remedy to the diffuser plates *seven* different times during the more than two weeks of smudge conditions. Each time the pressure was brought back to normal, and thus far we have been unable to detect any serious consequences in the operation of the plant. Altogether, we used seven and one-half gallons of aviation gasoline at the total cost of only $1.16 and feel pretty good at saving the trouble and cost of emptying the tanks, removing and cleaning the plates."

*Assistant Chief Engr., Los Angeles County Sanitation Districts.

SERVICING OF POROUS AIR DIFFUSERS*

By FRANK C. ROE

Director of Sanitary Sales, The Carborundum Co., Niagara Falls, N. Y.

To maintain the high efficiency of porous diffuser plates and tubes of the type used for aeration in sewage and water treatment plants, their operation should be checked regularly. Partial clogging of the porous structure may occur for a number of reasons, thereby decreasing the effectiveness and increasing the cost of aeration.

The writer and his company have made a study of the various methods of servicing diffusers necessary to maintain their efficiency for a reasonable life.

The most immediate and positive indication of obstruction within the diffuser structure is an increase of compressor or blower pressure necessary to supply a given quantity of air. Visual examination of the aeration tank or tanks will also disclose non-uniformity of diffusion which may be due to a partially clogged condition. This is a practical determination but not so conclusive as the first.

Diffusers may become clogged on either the air side or on the liquor side; that is, on the top or bottom of plates and on the outside or inside of tubes. Both classes of clogging may be experienced simultaneously, but are avoidable to a great extent.

Liquor Side Clogging

1. *Suspended Solids*: Perhaps the most common type of clogging is caused by interruption of aeration during which the solids in water, sewage, sludge or mixed liquor settle and the water content filters through the diffusers into the air duct. Most of the solids in suspension are intercepted at the diffuser surface, but a definite proportion, depending on the pore size, will enter the top 1/16 to ⅛ inch of the structure. When aeration is resumed all of these particles will not be blown out of the structure and cumulative clogging results.

Maintenance of continuous air delivery, at least to some degree, is the positive way to preclude this trouble. Temporary cessation of the air supply is not impossible with modern equipment, but the usual auxiliary blowers with standby power units and inexpensive automatic control equipment will largely eliminate shutdowns.

Care should also be taken not to over-design in the matter of diffuser area. Not less than one cubic foot of air per minute should normally be discharged per square foot of diffuser area. Insuring a higher rate, so as to maintain good air velocity through the pores as well as uniformity of diffusion from the entire diffuser area, is better practice still.

2. *Organic Growth*: Another form of liquor side clogging is growth of bacterial and protozoa life in the uppermost portion of the porous structure. This may be attributed, at least partially, to non-uniformity of diffusion. All of the diffusers controlled by a single valve may not have similar permeability ratings, or the individual areas of any particular diffuser plate or tube may not be uniform one with another.

As suggested, it should be possible to avert clogging of this nature by careful installation and selection of plates or tubes. All units controlled by a single air valve should have a similar permeability rating within limits of 0.5 cu. ft. or less. Uniformity of individual diffusers depends upon precision and perfection in manufacturing.

*Excerpts from an article appearing in WATER WORKS AND SEWERAGE, April 1934.

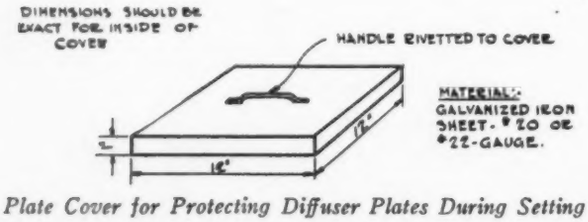


Plate Cover for Protecting Diffuser Plates During Setting

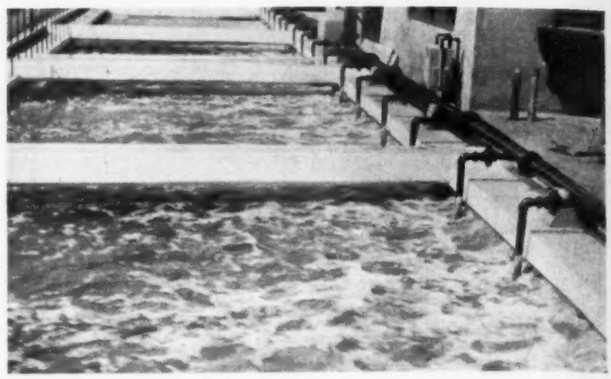


Plate 1—A Section of Aeration Tanks (Sewage Treatment Plant, Golden Gate Park, San Francisco), an Example of Uniform Diffusion

3. *Miscellaneous*: Very often protection from cement grout (or other material used to install plates), dirt, debris, etc., is not provided during installation or when tanks are empty, and appreciable surface clogging results. A plate cover (see sketch) should be used to shield plates from cementing materials during installation, and other protective measures should be observed when tanks are empty.

Air Side Clogging

1. *Dirt in Air*: Air containing a high quantity of soot or other impurities is a major source of clogging on the underside of diffuser plates or inside of diffuser tubes. Selection of effective air filters and care in locating the air intake are obvious preventatives.

The thought should be injected here that diffusers of higher permeability than the type used during the early days of sewage aeration are undoubtedly subject to less clogging of this nature because of relatively larger pores through which many of the fine suspended particles pass rather than stop. It is doubtful if the air bubbles released from higher permeability diffusers are very much larger than the bubbles discharged from the earlier low permeability grade of diffuser. The fact remains that higher permeability diffusers have not been less effective than those of lower ratings previously specified.

2. *Oil in Air*: Reciprocating compressors are now rarely used in sewage aeration, but the oil which they force through air lines is responsible for pronounced diffuser pore plugging. Fortunately, the low pressure required for sewage aeration permits the use of rotary blowers of the centrifugal or positive displacement type. If reciprocating units must be used for any reason, an oil trap or filter of some kind should be used between the compressors and the diffusers.

Certain types of primary air filters depend on the use of an oil for cleaning or renovating. In this operation it is recommended that a partial wash with a solvent be given after the oil treatment so that oil will not be blown free and carried through the diffusers.

3. *Air Pipe Rust or Scale*: It is generally recognized that cast iron pipe as a material for air lines is sufficiently resistant to corrosion from moisture to be considered to have almost an endless life. Genuine wrought iron is likewise considered satisfactory. Galvanized or sherardized steel pipe would be considered suitable for relative short periods of life, while ordinary black iron pipe or steel is not suitable.

In spite of the consideration given to this phase of air pipe design, there is evidence that some air side clogging is caused by iron oxide in the form of rust particles and scale.

There are economic considerations involved in preventing this source of clogging. Aluminum and copper pipe have been used

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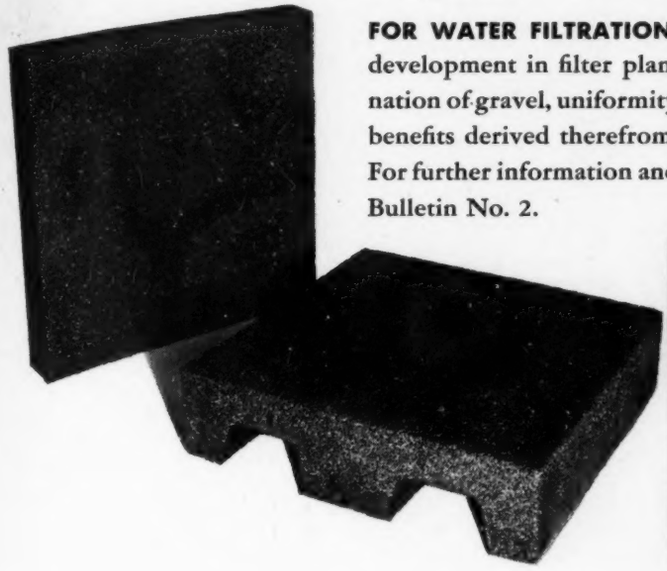

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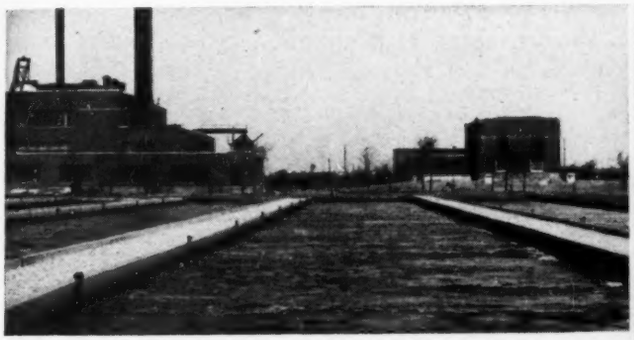

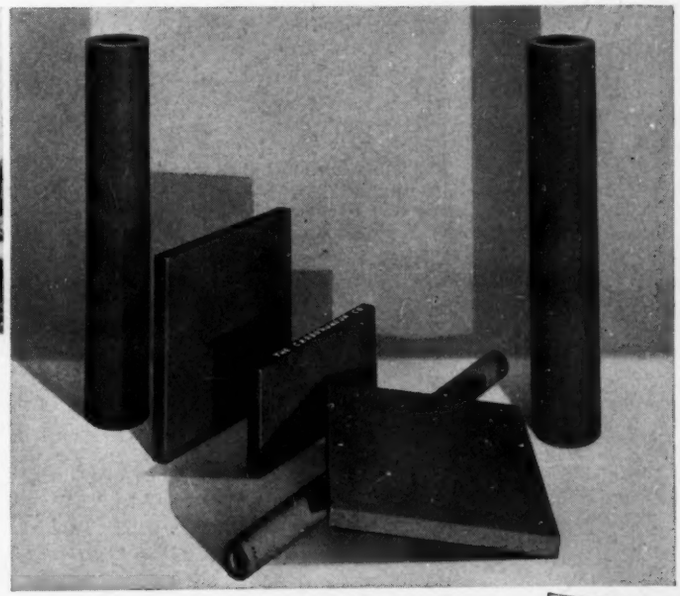

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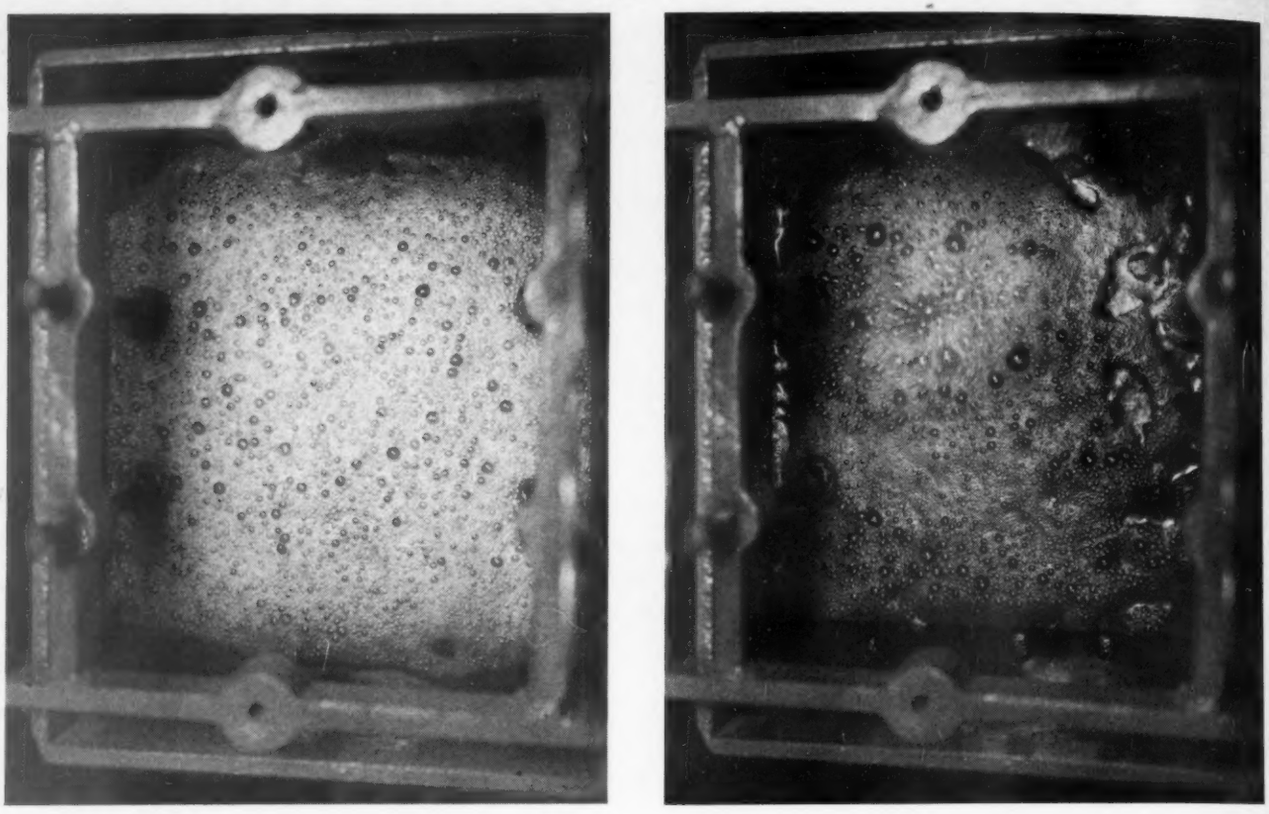


Plate 2—An Illustration of Good Uniformity of Diffusion on the Left; Poor Uniformity on the Right. (Photographs Taken Looking Down on Diffusion Plates in Testing Apparatus)

for the smaller air lines and are recommended along with other types of corrosion resistant pipe. However, if the use of such pipe raises the installation cost appreciably it should be balanced against the estimated cost of diffuser servicing and replacement.

4. *Miscellaneous*: Air lines left in a dirty condition after installation can cause clogging of considerable magnitude. The remedy is obvious. Cast iron diffuser plate containers may cause the same difficulty as does iron piping, but to a lesser degree. Mr. William M. Piatt has avoided this possible source of trouble in designing containers for some of his plants in North Carolina, by using aluminum container linings. At other plants the entire plate holder is to be of aluminum.

Restoration of Diffuser Efficiencies

Because of the diversified types and degrees of clogging experienced in the 100-odd activated sludge plants in the country, it is natural to expect that there are many methods of cleaning in use. Lacking information on the subject, plant superintendents and operators have, more or less successfully, devised and developed individual methods of their own.

Plate Cover for Protecting Diffuser Plates During Setting

The writer's company, in addition to considerable experimental work in the research laboratories. has fostered a survey among those in charge of plants throughout the United States and Canada, believing that many practical methods of diffuser cleansing would come to light. The response to our inquiries and the cooperation received has been most gratifying and has made it possible to present the outline to follow. Some of the methods have been improved, amplified or supplemented as the result of certain research work which we have conducted.

Methods employed in diffuser cleaning can be divided into two general classes; viz., methods applicable to diffusers in place (suitable largely to liquor side clogging) and methods which are adaptable only to removed diffusers. Tubes are cleaned for the most part by the latter method because they may be quickly and easily removed. The methods to follow are not given in an order to indicate preference.

Cleaning Diffusers in Place

1. *Caustic Treatment*: Clean aeration tank and surface of diffusers thoroughly with hose stream and leave about ½ in. of clean water over plates, providing the slowest practical air diffusion during this period. Dissolve about 1/10 lb. commercial lye crystals over each square foot of plate and then shut off air. Allow solution to penetrate plate (10 to 15 minutes), add more clean water, and then turn air on a maximum rate. (Note: This method is chiefly applicable to removal of organic compounds.)

2. *Sand Blasting*: Dry plates thoroughly by draining containers completely and blowing out porous structure with air

Plate 3—Diffuser Plates Stacked in Furnace for Burning-Out of Organic Matter. (More Clearance Between Plates Preferable; See Method 14)

applied at high rate. Sand blast plate surface with usual type of sand blast equipment, using "Blastite" Grain. Remove not more than 1/32 in. from surface, *maintaining maximum air discharge during the operation.* One minute or less is required to clean a plate by this method.

3. *Surface Spalling*: This method is applicable to diffuser plates of the silica type. Dry plates by draining containers and blowing out porous structure with air at high rate. Apply blow torch flame to entire top surface of plate until it cracks into flakes. Sweep off this film or scale and rub surface smooth with a Carborundum rubbing block. Sweep off particles again. Leave air on during entire operation.

4. *Burning Out Surface*: Dry plates by draining containers and blowing out porous structure with air at high rate. With air off, saturate each plate with one quart of alcohol and apply heat with blow torch. Dry and brush off surface.

5. *Acid Washing and Scrubbing*: Dry plates by draining containers and blowing out porous structure with air at high rate. With air off, apply a 30 per cent solution of hydrochloric (muriatic) acid to the surface liberally and allow same to penetrate somewhat before turning on air at a low rate. Scrub with a stiff brush, using more acid if necessary. Follow with a clean water wash and scrubbing with a wire brush, continuing air discharge at a somewhat higher rate. (Note: This method is chiefly applicable to removal of inorganic compounds.)

6. *Vacuum Cleaning*: This method has not been proven but was suggested by authorities at the Milwaukee Sewage Treatment Plant, where a trial was intended. A vacuum pump was to have been used with a suction inlet of small area which would be held closely against and moved back and forth across the diffuser surface to be cleaned.

7. *Rest*: Dry plates by draining containers and blowing out porous structure with air at high rate. Allow diffusers to rest while dry for a week or more. (Note: The theory of this treatment is that the change of conditions will cause the bacterial and protozoa growth in the porous structure to die.)

8. *Chlorine Treatment*:* Introduce a strong dose of chlorine into the branch air line leading to each diffuser assembly for several minutes during a low rate of air flow. Following by blowing out diffusers with the maximum possible rate of air flow. (Note: This method is chiefly applicable to removal of organic compounds and carbonates.)

9. *Steam Backwashing*:* Dry diffusers by draining and blowing out porous structure with air at high rate. Introduce steam into the branch air line at 10 lbs. pressure and scrub diffuser surface simultaneously with a stiff brush.

10. *Water Backwashing*:* Introduce clean water into the branch air line under pressure of 15 to 20 lbs. per sq. in. Scrub diffuser surface simultaneously with a stiff brush.

Cleaning Removed Diffusers

11. *Acid Pickling*: Wash diffusers with water (use hose and brush). Set in a vertical position and allow to drain and dry as much as possible. Soak in 30 per cent solution of hydrochloric or nitric acid for four hours. Wash with water. (Note: Use Hydrochloric acid if it is desired to dissolve inorganic compounds and nitric acid if it is desired to oxidize organic compounds.)

12. *Caustic Treatment*: Place diffusers in vessel containing a 10 per cent solution of sodium hydroxide (lye) and boil for about one hour. Remove from this solution and wash thoroughly in boiling water. (Note: This method is only applicable to partial removal of organic compounds, chiefly fats, which are saponified by the caustic soda and then dissolved in hot water.)

13. *Sandblasting*: Dry diffusers thoroughly (preferably in an oven of some kind) and sandblast (Method 2) on either or both sides, as required. It is recommended that, where practicable, the diffuser be inserted in a container which will make it possible to force air through it at a high rate during the operation. This will eliminate any clogging by the dust created.

*Methods applicable to tubes or plates and of some benefit also in cleansing the air size of diffusers.

14. *Burning*: This method is applicable to diffusers of the fused crystalline alumina type. Place diffusers in a furnace or kiln in any convenient position, leaving a space of not less than ½ in. between units. Raise temperature gradually during 10 hours to about 1000 deg. Centigrade and then allow to cool gradually. The cycle should take at least 16 hours. Fuel of any kind is satisfactory, but care must be taken to avoid impingement of flame against diffuser surfaces. At Decatur, Ill., gas from sludge digestion was used.

Selection of Method

Every plant operates under conditions peculiar to itself, which will prove a factor in the ease or difficulty of diffuser servicing and the methods of cleaning which can be, or should be, used. One method may work satisfactorily in one place but be wholly unsatisfactory in another place or at another time.

In general, methods used on diffusers *in place* are not better than 75 per cent effective and range down to as low as 10 per cent where the clogging is almost wholly on the air side. Methods of cleaning removed diffusers are much more effective and are from 60 to 95 per cent effective. It is usually a combination of two or more methods which will produce the best result; because, any single method is not a cure-all.

The combination of causes and degree of clogging vary greatly and therefore it is not possible to give a rating of effectiveness to each method of restoration. It can be stated, however, that acid pickling of removed diffusers (Method 11) followed by burning in a furnace or kiln (Method 14) is 90 to 100 per cent effective, regardless of type or degree of pore plugging. This combination is therefore, recommended where serious clogging exists.

A simple improvised furnace can usually be built at a sewage plant to refire diffusers, other considerations being satisfactory. Where this work proves impracticable in the field, the writer's company will use its kilns at Niagara Falls for refiring when requested. Such arrangements would offer an added advantage in that refired diffusers can easily be retested and rated so that they may be properly re-installed thereafter.

The above suggests the consideration of providing a simple permeability testing apparatus at sewage treatment plants which would be useful in re-rating removed diffusers which have been cleaned at the plant. Even though original markings are retained, which is doubtful, all units will not respond equally to the cleaning method employed and will have a new permeability rating which should be determined when re-installation is made.

For acid pickling (Method 11) a wooden tub is satisfactory. The caustic treatment requires an iron kettle because of the boiling operation. Workmen should use precaution in these methods by wearing rubber gloves, aprons, etc. Tongs can be used to handle diffusers.

Where existing plate containers do not permit simple mechanical plate removal, a joint composed of sand in the bottom ½ in. and cement grout in the top, is recommended for setting plates in holders. This will save time and avoid plate breakage when removal becomes necessary. Plates so installed should be set with a lime mortar under the supporting edges to insure an even bearing.

Conclusion

The practice of regular servicing should be stressed if the diffusers in any plant are subject to a known source of clogging. If this is done, whether it is apparently needed or not, the permeability will be maintained indefinitely, in all probability, and one or more of the simple and least costly methods of revivification can be employed.

Because of the several potential sources of diffuser pore plugging which exist, and because many of these cause air side clogging, the use of plate containers which permit easy removal of plates is recommended. Ease of removal and replacement is one of the important advantages of diffuser *tubes* for smaller plants.

Diffusers of high permeability are less subject to clogging because of larger pores. They operate on a slightly lower air pressure than low permeability diffusers. Because of these advantages, and the fact that effectiveness of aeration is not decreased (compared to that provided by low permeability diffusers), plates of a higher rating are recommended.

MENSURATION—Or Simplified Calculations

Calculating Areas, Volumes, Surfaces

Mensuration is arithmetic applied to geometry in determining the length of lines, the area of surfaces, and the volume of solids or bodies.

Definitions of geometrical terms, figures and principles. A point (.) has position only. A line (———) has length only. Area has length and breadth. A solid has length, breadth and thickness. Parallel means extended in the same direction, and equidistant at all points. Horizontal means parallel with water level; vertical or perpendicular, parallel with plumb line; diagonal, obliquely across a polygon. (Fig. 4.) Equilateral means, having equal sides. Quadrilateral, having four sides. An angle (Fig. 1) is formed by two straight lines diverging from a commont point called the vertex. A right angle (Fig. 2) is formed by two straight lines meeting perpendicularly. An oblique angle is either (acute—Fig. 1) smaller, or (obtuse—Fig. 3) greater than a right angle.

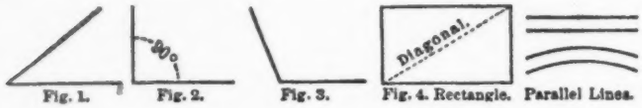


Fig. 1. Fig. 2. Fig. 3. Fig. 4. Rectangle. Parallel Lines.

A plane or plane figure has area or surface only—perfectly even.

A polygon is a plane figure having three or more equal sides.

A triangle is a plane figure bounded by three straight lines.

An equilateral triangle (Fig. 6) has all of its (3) sides equal. An isosceles triangle (Fig. 7) has two of its sides equal. A scalene triangle (Fig. 5) has none of its sides equal. The base is the side on which a geometrical figure is supposed to stand. The least distance between the base and the opposite angle dotted line (Fig. 7) or between parallel lines (Fig. 8) is called the perpendicular or altitude.

To find the area of a triangle. Rule—Multiply base by the altitude and take half of the product. Or, when the three sides are given. From half of the sum of the three sides, subtract each side separately; then multiply the half sum and the three remainders together and extract the square root. Find sq. ft. in a triangle, base 8 ft., altitude 9 ft.

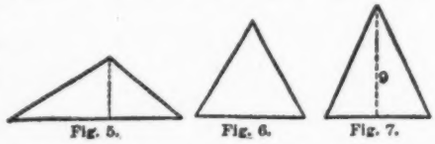


Fig. 5. Fig. 6. Fig. 7.

Answer—$(8 \times 9) \div 2 = 36$.

A parallelogram is a plane figure, bounded by four straight lines, whose opposite sides are equal, as a rectangle, a square, and a rhomboid.

A rectangle is a right angled parallelogram. A square is an equilateral rectangle. A rhomboid is an oblique angled parallelogram.

To find the area of a parallelogram. Rule—Multiply the length by the width.

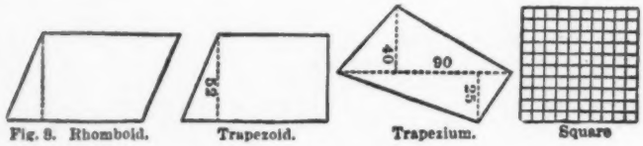


Fig. 8. Rhomboid. Trapezoid. Trapezium. Square

How many sq. ft. in a rectangle 17 by 24?

Answer—$17 \times 24 = 408$ sq. ft.

In a (square) floor 10 by 10?

Answer—$10 \times 10 = 100$ sq. ft.

Note—Dividing the area of a rectangle by one side gives the other side—if unknown.

A *trapezoid* is a quadrilateral having two of its sides parallel. To find its area. Rule—Multiply its average length by the width.

How many sq. yd. in a garden whose parallel sides are 60 and 80 yd., and width 52 yd.?

Answer—$(60 + 80 \div 2) = 70$; then, $70 \times 52 = 3{,}640$ sq. yd.

A *trapezoid* is a quadrilateral having two of its sides parallel.

To find its area. Rule—Form two triangles by a diagonal line, then multiply diagonal by sum of perpendiculars and take half of product.

Find sq. rods in field shaped like a trapezium, whose diagonal is 90 rods, and perpendiculars (25 and 40) 65 rd.

Answer—$90 \times 65 = 5850 \div 2 = 2925$ rd.

A *rightangled triangle* has one right angle. Its longest side is called hypotenuse, and the other two, base and perpendicular or altitude. To find its area. Rule—Multiply the base by the perpendicular and take half of the product.

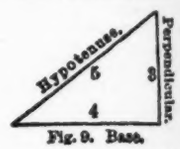


Fig. 9. Base.

How many square rods in a triangular field whose base is 70 rods and the perpendicular, 48 rods?

Answer — $(70 \times 48) \div 2 = 1680$ square rods.

Properties of the rightangled triangle. The square of the hypotenuse equals the sum of the squares of the base and the perpendicular. From this principle — illustrated by Fig. 10—we derive the following rules.

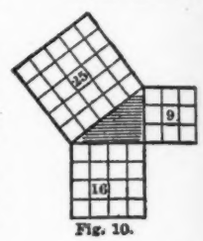


Fig. 10.

To find the hypotenuse. Rule—Add the square of the base and the square of the perpendicular, and of the sum extract square root.

A and B start from the same point, A going 4 miles due west and B, 3 miles due north; how far apart are they then?

$4^2 = 16$
$3^2 = 9$
$\sqrt{25} = 5$

Answer—5 miles.

The square of 4 (base)$=16$; of 3 (perpendicular)$=9$; the square root of their sum $(25)=5$, the hypotenuse.

To find the base or perpendicular. Rule—From the square of the hypotenuse, subtract the square of the other given side, and of their difference extract the square root.

Find the perpendicular of a triangular field whose hypotenuse is 75 rods, base 60 rods. Answer—45 rods.

$75^2 = 5625$
$60^2 = 3600$
$\sqrt{2025} = 45$

Note—To find the difference between the squares of two numbers, simply multiply their sum by their difference.

To find the side of a square equal in area to any given quantity. Rule—Extract the square root of the given quantity.

Thus, the dimensions of a square field containing 4000 square rods must be $(\sqrt{4000} = 63.246)$ $63\frac{1}{4}$ rods, nearly. Proof: $63\frac{1}{4}^2 = 4000+$

To find the diagonal of a square. Rule—Multiply one side of the square by 10, diminish the product by 1% of itself and divide remainder by 7.

What is the diagonal of a field 35 rods square?

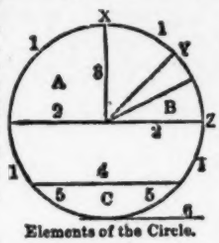
This is a simple way of finding the hypotenuse of a triangle whose base and perpendiculars are equal.

$35 \times 10 = 350$.
1% of $350 = 3.5$
$7)346.5$
Ans. (rd.) 49.5

The Circle

A circle is a plane figure bounded by a curved line, (1, 1, 1, 1) called circumference, every point of which is equally distant from

the center. The diameter is a straight line (2, 2) across a circle, through its center. The radius is a straight line (3) from the center to the circumference. An arc is any part of the circumference (5, 5). A chord, a straight line (4) joining ends of an arc. A tangent (6) touches circum. without cutting it. A segment is space (C) enclosed by arc and chord. A sector, space (B) enclosed by two radii and arc. A quadrant (A) is 90° or the fourth part of circle. A circle is divided into 360°; from X to Y is 45°; from X to Z, 90°. A sextant is one-sixth of a circle.



Elements of the Circle.

To find the *circumference* of a circle, the diameter being given. Rule—Multiply the diameter by 3 1/7; for greater accuracy, by 3.1416.

Find circumference of bicycle wheel; diam. 28 in.

Answer—$28 \times 3\,1/7 = 88$ in.

To find the *diameter* of a circle, the circumference being given. Rule—Divide the circumference by 3 1/7, or multiply it by .3183.

Circumference of a tree 144½ in., find diam.

Answer—$144.5 \times 3183 = 46$ in.

To find the *area* of a circle. Rule—Multiply the square of the diameter by .7854; or the square of the radius by 3.1416; or the square of the circumference by .07958.

Find the area of a piston 20 in. in diam.

Answer—$20^2 \times .7854 = 314.16$ sq. in.

Over how many sq. ft. can a cow graze, staked to a rope 50 ft. long? Here, 50 feet is the radius.

Answer—$50^2 \times 3.1416 = 7854$ sq. ft.

To find the *radius* of a circle, the area being given. Rule—Multiply the area by .3183 and extract the square root of the product.

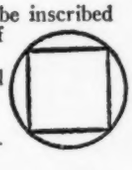
Find length of halter, tied to stake, that will enable horse to graze on 1 acre.

Answer—Square feet in acre, $43560 \times .3183 = 13865$; $\sqrt{13865} = 117¾$ ft. long.

Note—The circumference of a circle is 3.1416 times greater than the diameter. The number 3.1416 (called Pi); its reciprocal, .3183; its 4th part .7854, its 6th part .5236, and others, should be committed to memory as they are indispensable factors in computing the areas and volumes of circular figures and bodies.

To find the *area of a sector* of a circle. Rule—Take such a part of the circle as the degrees in the given arc, are part of 360. Thus, a sector whose arc is 40°, contains 40/360 or 1/9 of the area of the circle.

To find the side of the greatest square that can be inscribed in a given circle. Rule—Multiply the diameter of the circle by .707; or the circumference by .225.



The diameter of a log is 24 inches; how large a sill can be cut from it?

$24 \times .707 = 17$ in. square, nearly.

To inscribe the greatest equilateral triangle. Rule—Multiply the diameter of the circle by .886.

Side of greatest inscribed hexagon equals the radius of a circle.

To find the diameter of a circle that will inscribe a given square. Rule—Multiply the side of the desired square by 1.414.

What must be diam. of a log to cut a sill 12 in. sq.?

Answer—$12 \times 1.414 = 17$ in.

The area of the greatest square inscribed in a given circle is exactly ½ of the area of the least square circumscribed about the same circle—or the square of its diameter.

To find the area between the two *concentric circles*. Rule—Take the difference between the area of each circle. A simpler way is to multiply the sum of the two diameters by their difference, and the product by .7854.

Find the area included between two concentric circles whose diameters are 30 and 50 inches. (80, sum; 20, dif.)

Answer—$20 \times 80 = 1600 \times .7854 = 1256.64$ sq. in.

To find the diameter of a circle whose area is equal to the area of a given square. Rule—Multiply one side of the given square by 1.1284.

To find the side of a square whose area is equal to the area of a given circle. Rule—Multiply the diameter of the given circle by .8862.

To find the diameter of three greatest equal circles that can be inscribed in a given circle. Rule—Multiply the diameter of the given circle by .464.

Find the diameters of the three greatest circles that can be inscribed in a circle 50 in. in diam.

Answer—$50 \times .464 = 23.2$ in.

An *ellipse* is a plane figure bounded by an oval curved line and has a long and a short diameter or axis.

To find its circumference. Rule—Multiply the sum of the two diameters by 3.1416, and take half of the product.

Ellipse.

Find the circumference of an ellipse whose diameters are .41 and 29 ft.

$(41 + 29) = 70 \times 3.1416 \div 2 = 110$ ft. nearly.

To find the *area of an ellipse*. Rule—Multiply the product of the two diameters by .7854.

How many square ft. are there in an elliptical platform whose diameters are 60 and 40 ft.?

$60 \times 40 = 2400 \times .7854 = 1885$ sq. ft. nearly.

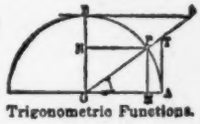
Polygons

To find the area of polygons, having equal sides and equal angles. Rule—Multiply the square of one of the equal sides—of a triangle, by .433; of a pentagon, by 1.7205; of hexagon, by 2.5981; of octagon, by 4.8284.

One side of an equilateral triangle is 30 inches, and of an octagon, 10 in.

Find sq. in. in each.

$30^2 \times 433 = 389.7$ in. T; $10^2 \times 4.824 = 482.84$ in. O.


Trigonometric Functions.

For the benefit of those who intend to study trigonometry and surveying, this illustration is inserted here. It will be an advantage and saving of time to be already familiar with the terms and the functions of the science when beginning its study.

P M, sine.
O M, cosine.
A T, tangent.
B S, cotangent.
O T, secant.
O S, cosecant.
M A_1, versed sine.
B N, conversed sine.

Cubes, Cones, Pyramids, Spheres,

A *cube* is a solid body, having six equal square sides. To find its area. Rule—Multiply area of one side by 6. To find its volume. Multiply the length, the breadth and the thickness together.

Cube.

Find sq. in. in surface of a 12 in. cube.

Answer—$12^2 \times 6 = 864$.

How many cubic in. in a cubic foot?

Answer—$*12^3 = 1728$.

Find cu. ft. in a cu. mile.

Answer—$5280^3 = 147197952000$.

A *parallelopiped* is a solid body whose six faces are all rectangles. To find its area. Rule—Add areas of its six sides. To find its volume. Same as the cube. How many cubic feet in a wagon bed 10½ feet long, 3 ft. wide and 1¼ ft. deep?

Parallelopiped.

Answer—$10½ \times 3 \times 1¼ = 39⅜$.

A *prism* is a solid having three or more rectangular sides, whose ends or bases are parallel plane figures. To find its area. Rule—Add areas of the sides and ends. To find its volume. Multiply the area of one end by the length.

Prism.

Find the area of a triangular prism, each of whose three sides are 10 by 25 inches.

Answers—836.6 sq. in.

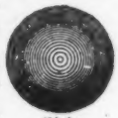
$10^2 \times .433 \times 2 = 86.6$ sq. in. in area of the two ends.

$10 \times 25 \times 3 = 750$ sq. in. area of sides. $86.0 + 750 = 836.6$.

How many cubic inches in above prism, 10 by 25 inches?

Answer—$10^2 \times .433 = 43.3 \times 25 = 1082½$ cu. in.

A *globe* or *sphere* is a solid body, bounded by a uniformly curved surface. To find its area. Rule—Multiply the square of diameter by 3.1416; or the square of the circumference by .3183. To find its volume. Multiply the cube of diameter by .5236.


Globe.

How many square in. in the surface; and how many cubic in. in the volume of a globe 12 in. in diameter?

Answer—904.78 cu. in. $12^2 \times 3.1416 = 452.39$ sq. in. $12^3 \times .5236 = 904.78$ cu. in.

How many cubic miles in the earth, its diameter being nearly 8000 miles?

Answer—$2000^3 \times .5236 = 268083200000$ cubic mi.

Find greatest cube inscribed in a 26 in. globe.

Answer—$26 \times .577 = 15$ in.

To find the dimensions of a cube, equivalent in volume to a given globe. Rule—Multiply the diameter of given globe by 806.

To find the diameter of a globe, equivalent in volume to a given cube. Rule—Multiply one side of the cube by 1.2407.

A *cylinder* is a round body of uniform diameter whose ends are parallel plane figures. To find its area. Rule—Multiply the circumference by the length and to the product add the areas of both ends. To find its volume. Multiply the area of one end by length.

Cylinder.

Find the area of a cylinder 30 inches in circumference and 40 inches long.

Answer—1343.24 sq. in.

$30 \times 40 = 1200$ sq. in. in convex surface.

$30^2 \times .07958 \times 2 = 143.24$ sq. in. in the two ends.

Find cubic in. in a cylinder, diameter, 20 in, length 50 in.

Answer—$20^2 \times .7854 \times 50 = 15708$ cu. in.

A *cone* is a solid, which has a circular base and tapers uniformly to a point called vertex.

A *pyramid* is a solid, resembling a cone, having three or more triangular sides.

Cone.

Pyramid.

To find the area of a *cone or pyramid*. Rule—Multiply the circumference or perimeter of the base by the slant height, and to half of the product, add the area of the base.

Find the area or surface of a cone whose circumference at base is 40 in., and slant height 50 in.

Answer—1127.33 sq. in.

$50 \times 40 \div 2 = 1000$ sq. in. in convex surface.

$40^2 \times .07958 = 127.33$ in. base.

To find the volume of a cone or pyramid. Rule—Multiply the area of the base by the height and take ⅓ of the product.

How many cubic feet in a 6 sided pyramid, 10 ft. high, whose perimeter, at base is 15 ft. or each side 2½ ft.?

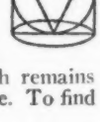
Answer—54.13 cu. ft.

$2\frac{1}{2}^2 \times 2.598 = 16.24$, area of base. $10 \times 16.24 \div 3 = 54.13$.

Find cu. in. in a cone whose height is 12½ in., and diameter of base 10 in.

Answer—$10^2 \times .7854 = 78.54$ area of base. $78.54 \times 12\frac{1}{2} \div 3 = 32.25$ cu. in.

The solid contents of the cone, globe, cylinder and the cube, all of equal dimensions, are in the ratio of 1, 2, 3 and 3.82 respectively. Thus, taking 1 foot as the height and the diameter; the cone contains .2618; the globe .5236, and the cylinder .7854 of a cubic foot. The cube equals 1 cu. ft.



The *frustum of a cone or pyramid* is the part which remains after cutting off the top, parallel to the plane of the base. To find the area of a frustum. Rule—Multiply the sum of circumferences, or perimeters, by the slant height, and to half of the product, add the area of each base.

Frustums.

Find the *area of a frustum* of a cone, whose slant height is 40 in., its greater circumference, 30 in., and its smaller one, 10 in.

Answer—879.58 sq. in.

$30 + 10 \times 40 \div 2 = 800$, sides. $30^2 + 10^2 \times .07958 = 79.58$, area of bases.

To find the *volume of any frustum*. Rule—Square both ends of one side, if angular, or the diameters of both ends or bases, if round. To the two squares add the product of the given ends or diameters; ⅓ of this sum will be the area of the average base of the frustum of a square pyramid, which multiplied by .7854 equals area of average base of frustum of a cone; multiplied by .433, of a three sided frustum, by 1.7205, of a five sided fr., by 2.5981, of a six sided frustum, by 4.8284, of an eight sided frustum. For volume: multiply average area by perpendicular height.

Find the volume or capacity of a round tank whose diameter is 15 ft. at base, 12 ft. at top, and 10 ft. deep. Ans.—14.37 cu. ft.

$12^2 = 144$
$15^2 = 225$
$12 \times 15 = 180$

3)549(183, area of av. base of F. of sq. pyr.

$183 \times .7854 = 143.73$ sq. ft., area of av. base of Fr. of cone.

$143.73 \times 10 = 1437.3$ cu. ft. $\times 7.48 = 10751$ gallons.

Find sq. ft. of lumber in a wagon tongue; large end, 4½ in. sq., small end, 2½ in., length, 9 ft. (108 in.).

Answer—$4\frac{1}{2} + 2\frac{1}{2}^2 + (4\frac{1}{2} \times 2\frac{1}{2}) \div 3 = 12\ 7/12$ sq. in., area of average base; $12\ 7/12 \times 108 = 1359$ cu. in. $\div 144 = 9\ 7/16$ sq. ft.

How many cu. ft. in a straight log, whose diameter at large end is 3 ft., small end, 2 ft., length 12 ft?

Answer—$3^2 + 2^2 + (3 \times 2) \div 3 \times .7854 = 4.974$ sq. ft., area of average base; $4.974 \times 12 = 59.69$ cu. ft.

A *spheroid* or elongated globe has a fixed and a revolving axis. To find its area. Rule—Multiply the revolving axis by the fixed axis, and that product by 3.1416. To find its volume. Rule—Multiply the square of the revolving axis by the fixed axis and that product by .5236. Find area, also the volume of spheroid; revolving axis, 20 in., fixed, 30 in.

Spheroid

$20 \times 30 \times 3.1416 = 1884.96$ sq. in. in area.

$20^2 \times 30 \times .5236 = 6283.2$ cu. in. in volume.

A *cylindrical ring* is formed by bending a cylinder. To find its area. Rule—Multiply sum of inside diam. and thickness of ring, by thickness, and the product by 9.87. To find its volume. Rule—Multiply sum of inside diam. and thickness, by square of thickness, and product by 2.467.

Ring.

Find the area, also the volume of a ring whose inner diameter is 15 inches, and whose thickness is 5 inches.

$(15 + 5) \times 5 \times 9.87 = 987$ sq. in. in area. $(15 + 5) \times 5^2 \times 2.467 = 1233.5$ cu. in vol.

To find the dimensions of *greatest cube that can be inscribed in a given globe*. Rule—Multiply the diameter of the globe by .577.

The above material has been drawn from "Ropp's Calculator"—an extremely useful and inexpensive little booklet published by C. Ropp & Sons, of Chicago.

Cylindrical Tank Capacities Per Foot of Depth

(The Cubic Foot Figure Is Also the Area in Each Instance)

Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.
1	0.785	5.87	9	63.62	475.9	20	314.2	2350	32	804.3	6016	58	2642	19760
1-3	1.227	9.18	9-6	70.88	530.2	20-6	330.1	2469	33	855.3	6398	60	2827	21150
1-6	1.767	13.22	10	78.54	587.5	21	346.4	2591	34	907.9	6792	62	3019	22580
1-9	2.405	17.99	10-6	86.59	647.7	21-6	363.1	2716	35	962.1	7197	64	3217	24060
2	3.142	23.50	11	95.03	710.9	22	380.1	2844	36	1018	7616	66	3421	25590
2-3	3.976	29.74	11-6	103.9	777.0	22-6	397.6	2974	37	1075	8043	68	3632	27170
2-6	4.909	36.72	12	113.1	846.0	23	415.5	3108	38	1134	8483	70	3848	28790
2-9	5.940	44.43	12-6	122.7	918.0	23-6	433.7	3245	39	1195	8940	72	4072	30450
3	7.069	52.88	13	132.7	992.9	24	452.4	3384	40	1257	9404	74	4301	32170
3-3	8.296	62.06	13-6	143.1	1071	24-6	471.4	3527	41	1320	9876	76	4536	33930
3-6	9.621	71.97	14	153.9	1152	25	490.9	3672	42	1385	10360	78	4778	35740
3-9	11.04	82.62	14-6	165.1	1235	25-6	510.7	3820	43	1452	10860	80	5027	37600
4	12.57	94.00	15	176.7	1322	26	530.9	3972	44	1521	11370	82	5281	39500
4-6	15.90	119.0	15-6	188.7	1412	26-6	551.5	4126	45	1590	11900	84	5542	41450
5	19.63	146.9	16	201.1	1504	27	572.6	4283	46	1662	12430	86	5809	43450
5-6	23.76	177.7	16-6	213.8	1600	27-6	594.0	4443	47	1735	12980	88	6082	45490
6	28.27	211.5	17	227.0	1698	28	615.8	4606	48	1810	13540	90	6362	47590
6-6	33.18	248.2	17-6	240.5	1799	28-6	637.9	4772	49	1886	14110	92	6648	49720
7	38.48	287.9	18	254.5	1904	29	660.5	4941	50	1964	14690	94	6940	51920
7-6	44.18	330.5	18-6	268.8	2011	29-6	683.5	5113	52	2124	15890	96	7238	54140
8	50.27	376.0	19	283.5	2121	30	706.9	5288	54	2290	17130	98	7543	56420
8-6	56.75	424.5	19-6	298.6	2234	31	754.8	5646	56	2463	18420	100	7854	58750

WATER PRESSURE

Feet of Heat — Pressure

Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in
1	0.43	54	23.39	107	46.34	160	69.31	213	92.20	285	123.45
2	0.86	55	23.82	108	46.78	161	69.74	214	92.69	290	125.62
3	1.30	56	24.26	109	47.21	162	70.17	215	93.13	295	127.78
4	1.73	57	24.69	110	47.64	163	70.61	216	93.56	300	129.95
5	2.16	58	25.12	111	48.08	164	71.04	217	92.99	305	132.12
6	2 59	59	25.55	112	48.51	165	71.47	218	94.43	310	134.28
7	3.03	60	25.99	113	48.94	166	71.91	219	94.86	315	136.46
8	3.46	61	26.42	114	49.38	167	72.34	220	95.30	320	138.62
9	3.89	62	26.85	115	49.81	168	72.77	221	95.73	325	140.79
10	4.33	63	27.29	116	50.24	169	73.20	222	96.16	330	142.95
11	4.76	64	27.72	117	50.68	170	73.64	223	96.60	335	145.12
12	5.20	65	28.15	118	51.11	171	74.07	224	97.03	340	147.28
13	5.63	66	28.58	119	51.54	172	74.50	225	97.46	345	149.45
14	6.06	67	29.02	120	51.98	173	74.94	226	97.90	350	151.61
15	6.49	68	29.45	121	52.41	174	75.37	227	98.33	355	153.78
16	6.93	69	29.88	122	52.84	175	75.80	228	98.76	360	155.94
17	7.36	70	30.32	123	53.28	176	76.23	229	99.20	365	158.10
18	7.79	71	30.75	124	53.71	177	76.67	230	99.63	370	160.27
19	8 22	72	31.18	125	54.15	178	77.10	231	100.0	375	162.45
20	8.66	73	31.62	126	54.58	179	77.53	232	100.49	380	164.61
21	9.09	74	32.05	127	55.01	180	77.97	233	100.93	385	166.78
22	9.53	75	32.48	128	55.44	181	78.40	234	101.36	390	168.94
23	9.96	76	32.92	129	55.88	182	78.84	235	101.70	395	171.11
24	10.39	77	33.35	130	56.31	183	79.27	236	102.23	400	173.27
25	10.82	78	33.78	131	56.74	184	79.70	237	102.66	425	184.10
26	11.26	79	34.21	132	57.18	185	80.14	238	103.09	450	195.0
27	11.69	80	34.65	133	57.61	186	80.57	239	103.53	475	205.77
28	12.12	81	35.08	134	58.04	187	81.0	240	103.96	500	216.58
29	12.55	82	35.52	135	58.48	188	81.43	241	104.39	525	227.42
30	12.99	83	35.95	136	58.91	189	81.87	242	104.83	550	238.25
31	13 42	84	36.39	137	59.34	190	82.30	243	105.26	575	249.09
32	13.86	85	36.82	138	59.77	191	82.73	244	105.69	600	259.90
33	14.29	86	37.25	139	60.21	192	83.17	245	106.13	625	270.73
34	14.72	87	37.68	140	60.64	193	83.60	246	106.56	650	281.56
35	15.16	88	38.12	141	61.07	194	84.03	247	106.99	675	292.40
36	15.59	89	38.55	142	61.51	195	84 47	248	107.43	700	303.22
37	16.02	90	39.08	143	61.94	196	84.90	249	107.86	725	314.05
38	16.45	91	39.42	144	62.37	197	85 33	250	108.29	750	324.88
39	16.89	92	39.85	145	62.81	198	85.76	251	108.73	775	335.72
40	17.32	93	40.28	146	63.24	199	86.20	252	109.16	800	346.54
41	17.75	94	40.72	147	63.67	200	86.63	253	109.59	825	357.37
42	18.19	95	41.15	148	64.10	201	87 07	254	110.03	850	368.20
43	18.62	96	41.58	149	64.54	202	87.50	255	110.46	875	379.03
44	19.05	97	42.01	150	64.97	203	87.93	256	110.89	900	389.86
45	19.49	98	42.45	151	65.40	204	88.36	257	111.32	925	400.70
46	19.92	99	42.88	152	65.84	205	88.80	258	111.76	950	411.54
47	20.35	100	43.31	153	66.27	206	89.21	259	112.19	975	422.35
48	20.79	101	43.75	154	66.70	207	89.66	260	112.62	1000	433.18
49	21.22	102	44.18	155	67.14	208	90.10	261	113.06	1500	649.7
50	21.65	103	44.61	156	67.57	209	90.53	262	113.49	2000	866.3
51	22.09	104	45.05	157	68.0	210	90.96	270	116.96	3000	1299.5
52	22.52	105	45.48	158	68.43	211	91.39	275	119.12		
53	22.95	106	45.91	159	68 87	212	91.83	280	121.29		

Based on a density of 62.355 pounds per cu. ft. for water at 62°F.

Theoretical Horsepower

$$\text{Water Horsepower} = \frac{\text{G. P. M.} \times \text{Head in Feet}}{3960}$$

HEAD IN FEET

Gallons per minute — Ft.	10	15	20	25	30	35	40	45	50	60	75	90	100
10	03	04	05	06	08	09	10	.11	.13	.15	.19	.23	.25
15	.04	.06	.08	.09	.11	.13	.15	.17	.19	.23	.28	.34	.38
20	.05	.08	.10	.13	.15	.18	.20	.22	.25	.30	.38	.45	.50
25	.06	.10	.13	.16	.19	.22	.25	.28	.32	.38	.47	.57	.68
30	.08	.11	.15	.19	.23	.26	.30	.34	.38	.45	.57	.68	.75
35	.09	.13	.18	.22	26	.31	.35	.40	.44	.53	.66	.80	.88
40	.10	.15	.20	.25	.30	.35	.40	.45	.50	.61	.76	.91	1.01
45	.11	.17	.23	.28	34	.40	.45	.51	.57	.68	.85	1.02	1.14
50	.13	.19	.25	.32	.38	.44	.50	.57	.63	.76	.95	1.14	1.26
60	.15	.23	.30	.38	.46	.53	.61	.68	.76	.91	1.14	1.36	1.52
75	.19	.28	.38	.47	.57	.66	.76	85	.95	1.14	1.42	1.70	1.89
90	.23	.34	.45	.57	.68	.80	.91	1.02	1.14	1.36	1.70	2.04	2.27
100	.25	.38	.50	63	.76	.88	1 01	1.14	1.26	1 51	1.89	2.27	2.52
125	.32	.47	.63	.79	.97	1.10	1.26	1.42	1.58	1.89	1.37	2.84	3.16
150	.38	.57	.76	.95	1.14	1.32	1.52	1.70	1.89	2.27	2.84	3.41	3.79
175	.44	.66	.88	1.10	1.32	1.54	1.78	1.99	2.21	2.65	3.31	3.98	4.42
200	.50	.76	1 01	1.26	1.52	1.77	2.02	2.27	2.52	3 03	3.79	4.54	5.05
250	.63	.95	1.26	1.58	1.90	2.20	2.52	2.84	3.16	3.79	4.73	5.68	6.31
300	.76	1.14	1.51	1.90	2.27	2.65	3.03	3.41	3.79	4.54	5.68	6.82	7.58
350	.88	1.33	1.77	2.21	2.65	3.09	3.54	3.98	4.42	5 30	6.62	7.95	8.84
400	1.01	1 52	2.02	2.52	3.03	3.53	4.04	4.55	5.05	6.06	7.57	9 09	10.10
500	1.26	1.90	2.52	3.16	3 78	4.42	5.05	5.69	6.31	7 58	9.47	11.36	12.63
550	1.39	2.08	2.78	3.47	4.17	4.86	5.56	6.26	6.94	8.33	10.42	12.50	13.89
600	1.52	2.28	3.03	3.79	4.55	5.30	6.06	6.82	7.58	9.09	11.36	13.64	15.15
650	1.64	2.47	3.28	4.10	4.93	5.75	6.56	7 39	8.21	9.85	12.31	14.77	16.41
700	1.77	2.66	3.54	4.42	5.30	6.19	7.07	7.96	8.84	10.60	13.26	15.91	17.68
750	1.89	2.85	3.79	4.74	5.68	6 63	7 58	8.53	9.47	11.36	14.20	17.04	18.94
800	2.02	3.04	4.04	5.05	6.06	7.07	8.08	9.10	10.10	12.12	15.15	18.18	20.20
850	2.15	3.23	4 29	5.37	6.44	7.51	8.58	9.67	10.73	12.87	16.10	19.32	21.46
900	2.27	3.42	4.54	5.68	6.82	7.95	9.09	10.24	11.36	13 63	17.04	20.45	22.73
950	2.40	3.60	4 80	6.00	7.20	8.40	9.60	10.80	11.99	14.39	17.99	21.59	23.99
1000	2.52	3.79	5.05	6 31	7.58	8.84	10.10	11.36	12 63	15 15	18.94	22.73	25.25
2000	5.05	7.57	10.10	12.63	15.15	17.67	20.20	22.72	25.25	30.30	37.87	45.45	50.50
3000	7.57	11.37	15.15	18.94	22.72	26.51	30.30	34.09	37.88	45.45	56.81	68.18	75.75
4000	10.10	15.16	20.20	25 25	30.30	35.35	40 40	45.45	50.50	60.60	75.75	90.90	101.01

NOTE:—to get the BRAKE HORSEPOWER required by the pump use the following formula:—

$$\text{Brake Horsepower} = \frac{\text{G. P. M. x Head in Feet}}{\text{3960 x Effy. of the pump}}$$

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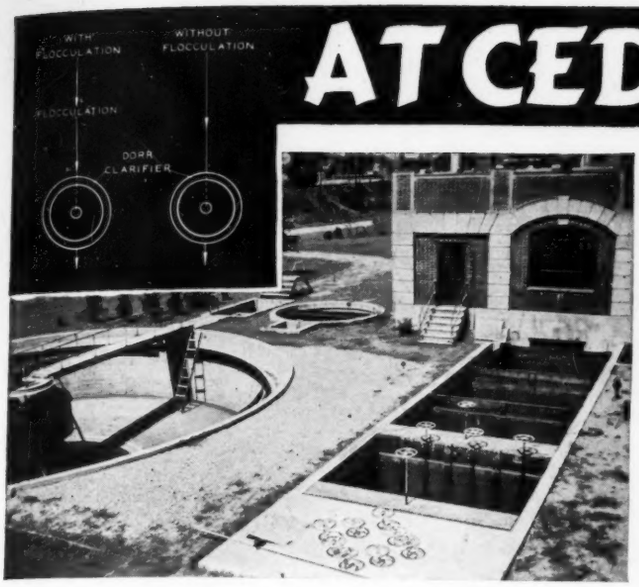

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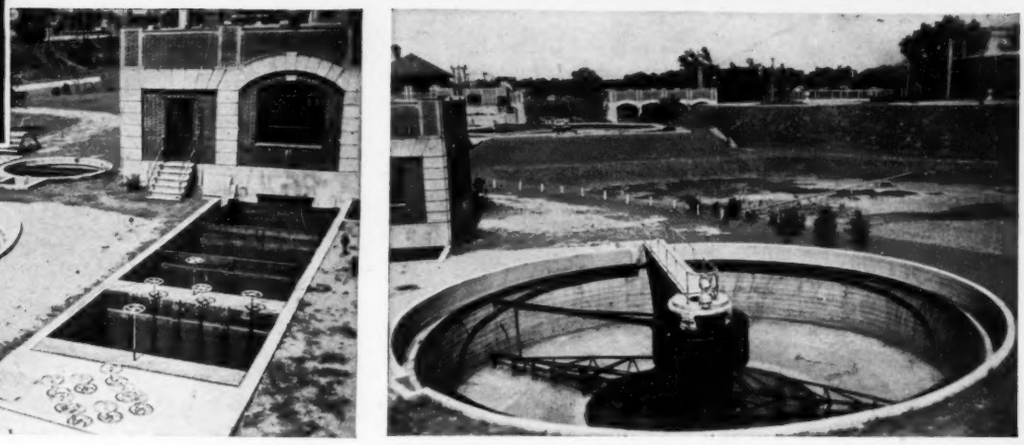

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THE above significant improvements in sewage sedimentation were demonstrated commercially at Cedar Rapids, Iowa on a mixture of raw sewage and packing house waste having an average B.O.D. of 346 p.p.m. and an average suspended solids content of 311 p.p.m.

Two 50 ft. dia. Dorr Sifeed Clarifiers were operated in parallel with identical feeds, one with and one without a Dorrco Flocculator for feed conditioning. No chemicals or other conditioning reagents whatsoever were used. Comparative operating data follow:

TABLE A* — Same Clarifier Detentions—50% Greater Removal Suspended Solids

TABLE B* — Same Removals Suspended Solids—3 Times Clarifier Capacity

	WEAK SEWAGE		STRONG SEWAGE		MEDIUM SEWAGE	
	With Flocculation	Without Flocculation	With Flocculation	Without Flocculation	With Flocculation	Without Flocculation
Detention—Clarifier	3.7 hrs.	3.7 hrs	1.5 hrs.	1.5 hrs.	1.20 hrs.	3.70 hrs.
Detention—Flocculator	1.4 hrs.	—	.5 hrs.	—	.45 hrs.	—
Raw Sewage—Suspended Solids—P.P.M.	226		411		285	
Suspended Solids Removal—Percent	69	46**	72.3	67.0	59.4	55.4
Raw Sewage—B.O.D. P.P.M.	291		410		294	
B.O.D. Reduction—Percent	35.4	18.5	29.0	23.6	17.7	13.4

*Excerpts from Table II of "Flocculation Studies," H. R. Green & M. C. McIntyre, Water Works & Sewerage, October 1937.
**Low removals due to colloidal condition of solids. Settleable solids removals at all times 99+%.

Engineers recognize that sewage treatment is not an exact science and that it is impossible to state that results obtained at one plant will be duplicated elsewhere. Only by chance does a similarity of influent, effluent and operating conditions prevail at two places.

The actual results reported above were obtained under well authenticated conditions and are of value as indicating the probable make up of the sewage treatment plant of the future. A Dorr engineer will gladly advise how these studies may point the way to improvements in your own operations.

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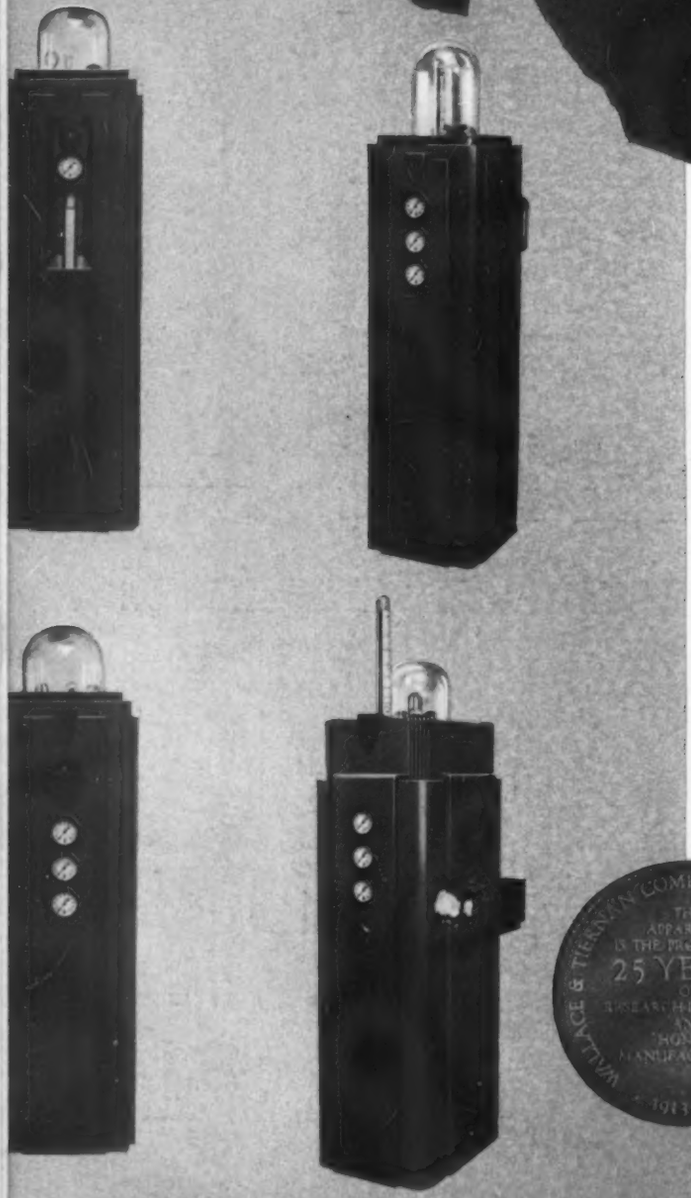

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